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February 1948

TECHNOLOGY REVIEW

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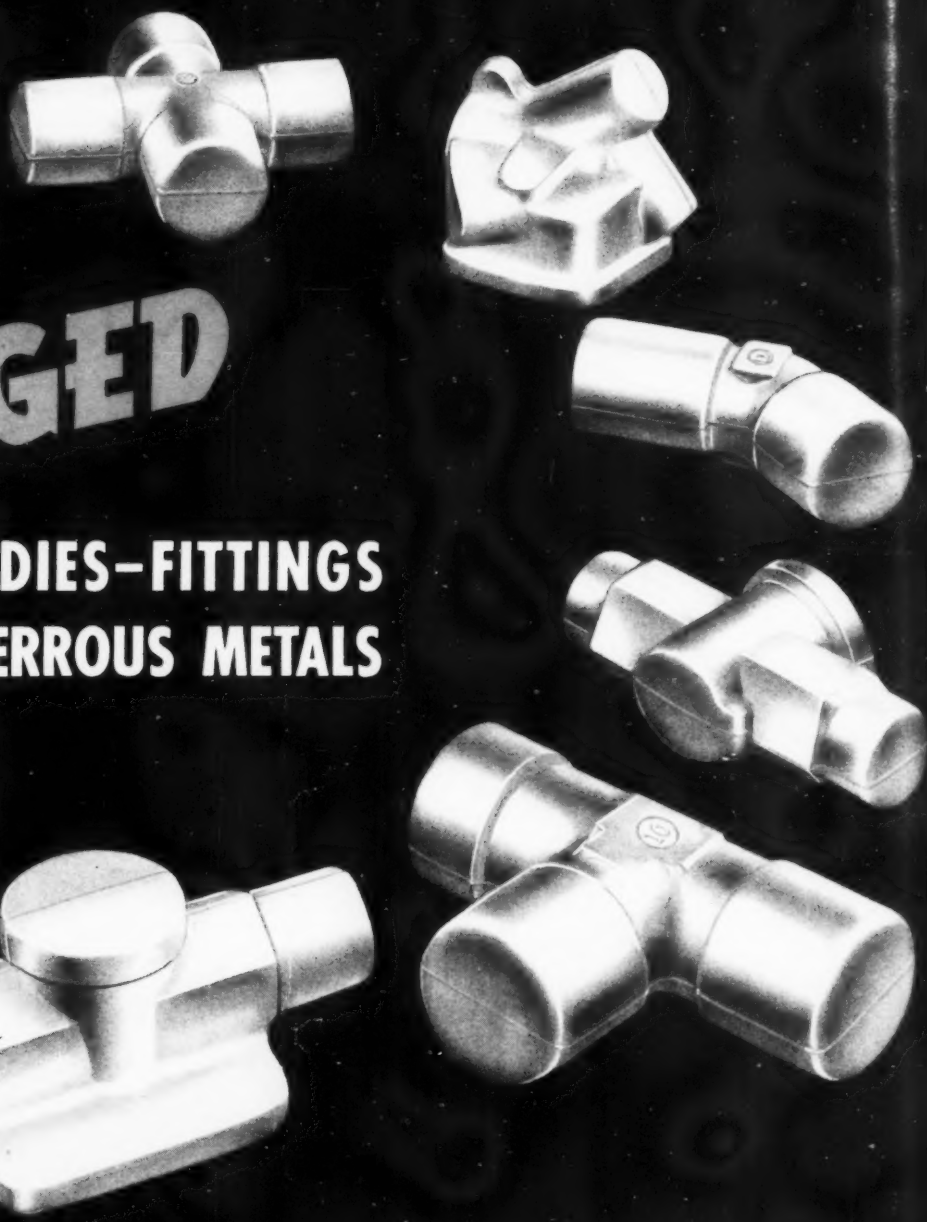

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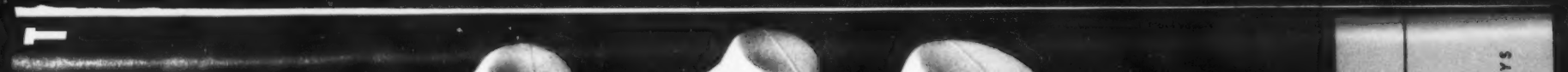

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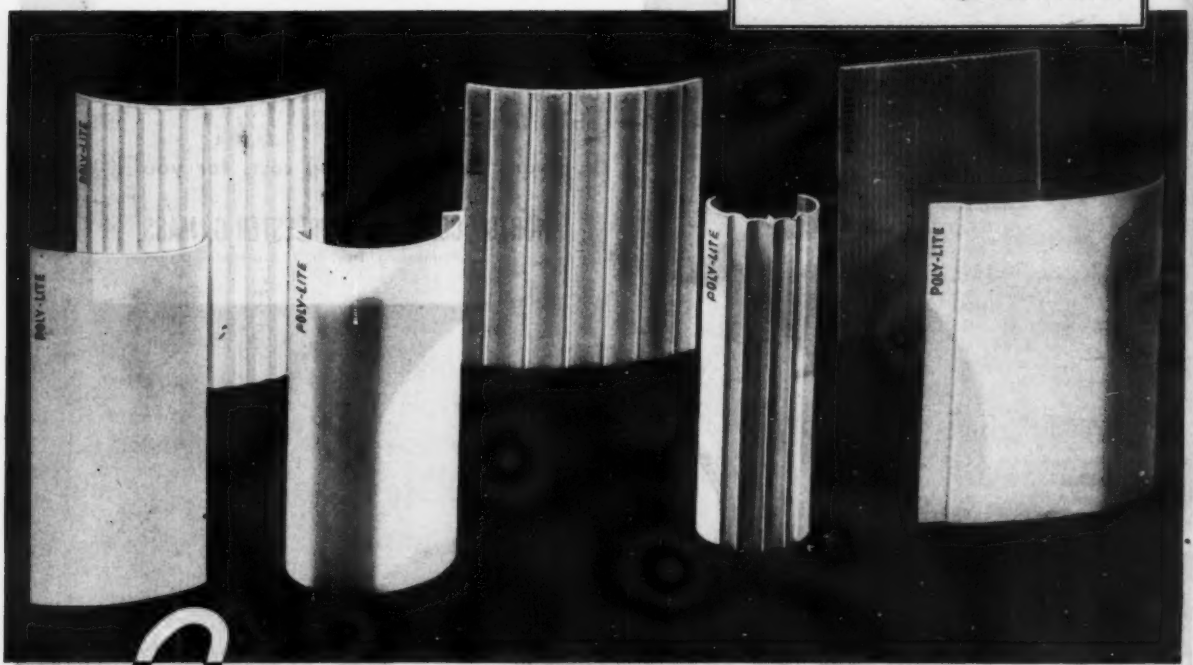

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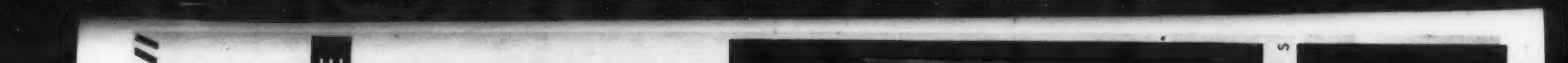

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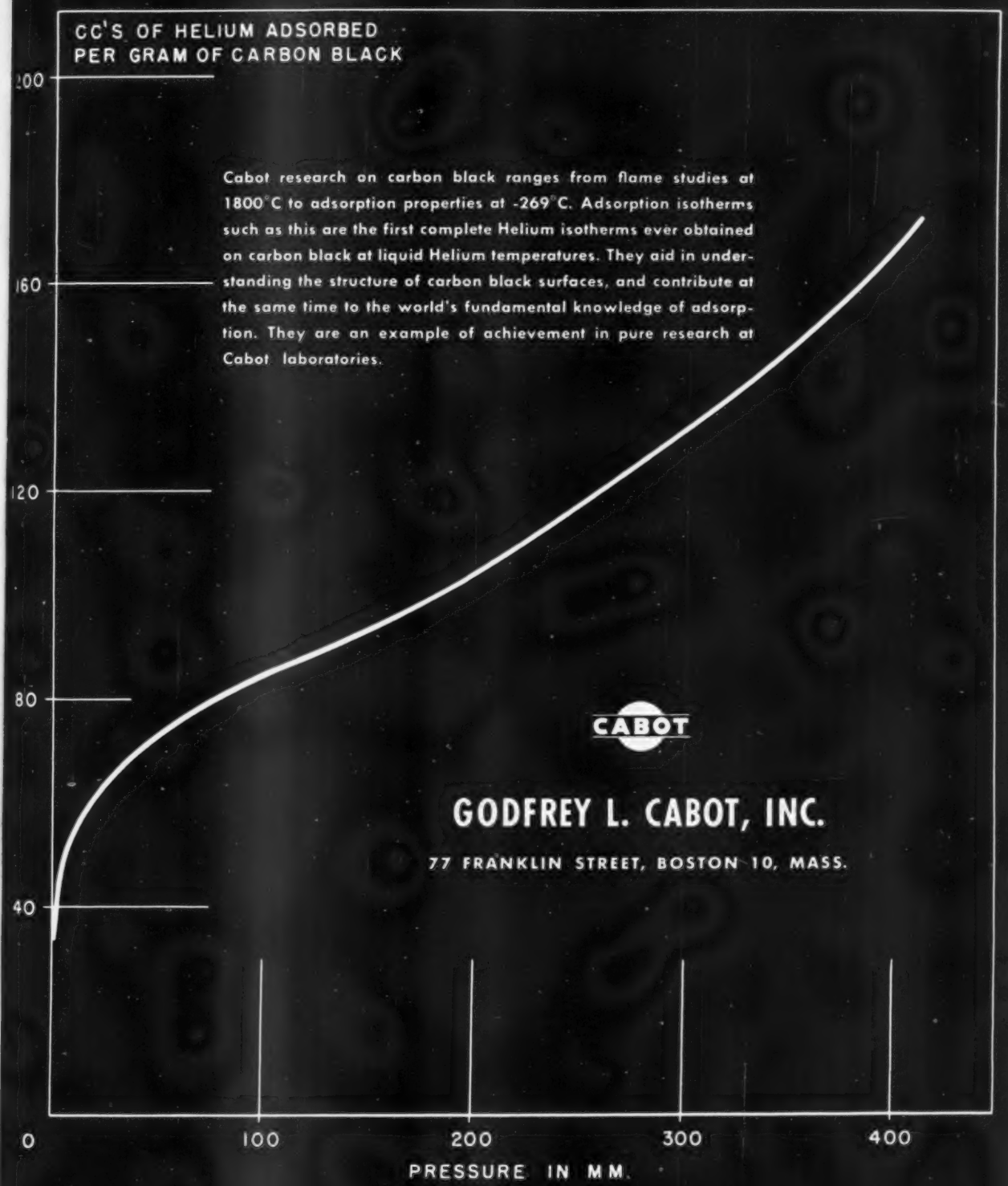
HELIUM ISOTHERM ON CABOT SPHERON 6
AT −269° C



Cabot research on carbon black ranges from flame studies at 1800°C to adsorption properties at -269°C. Adsorption isotherms such as this are the first complete Helium isotherms ever obtained on carbon black at liquid Helium temperatures. They aid in understanding the structure of carbon black surfaces, and contribute at the same time to the world's fundamental knowledge of adsorption. They are an example of achievement in pure research at Cabot laboratories.

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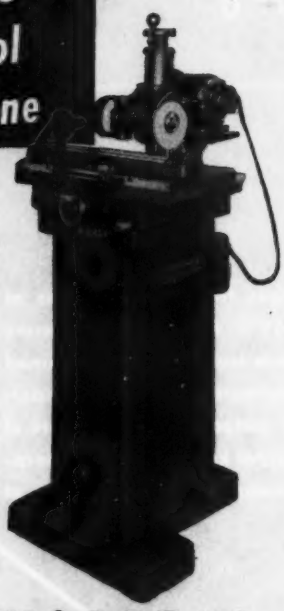

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Write for Bulletin S-4611

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THE TABULAR VIEW

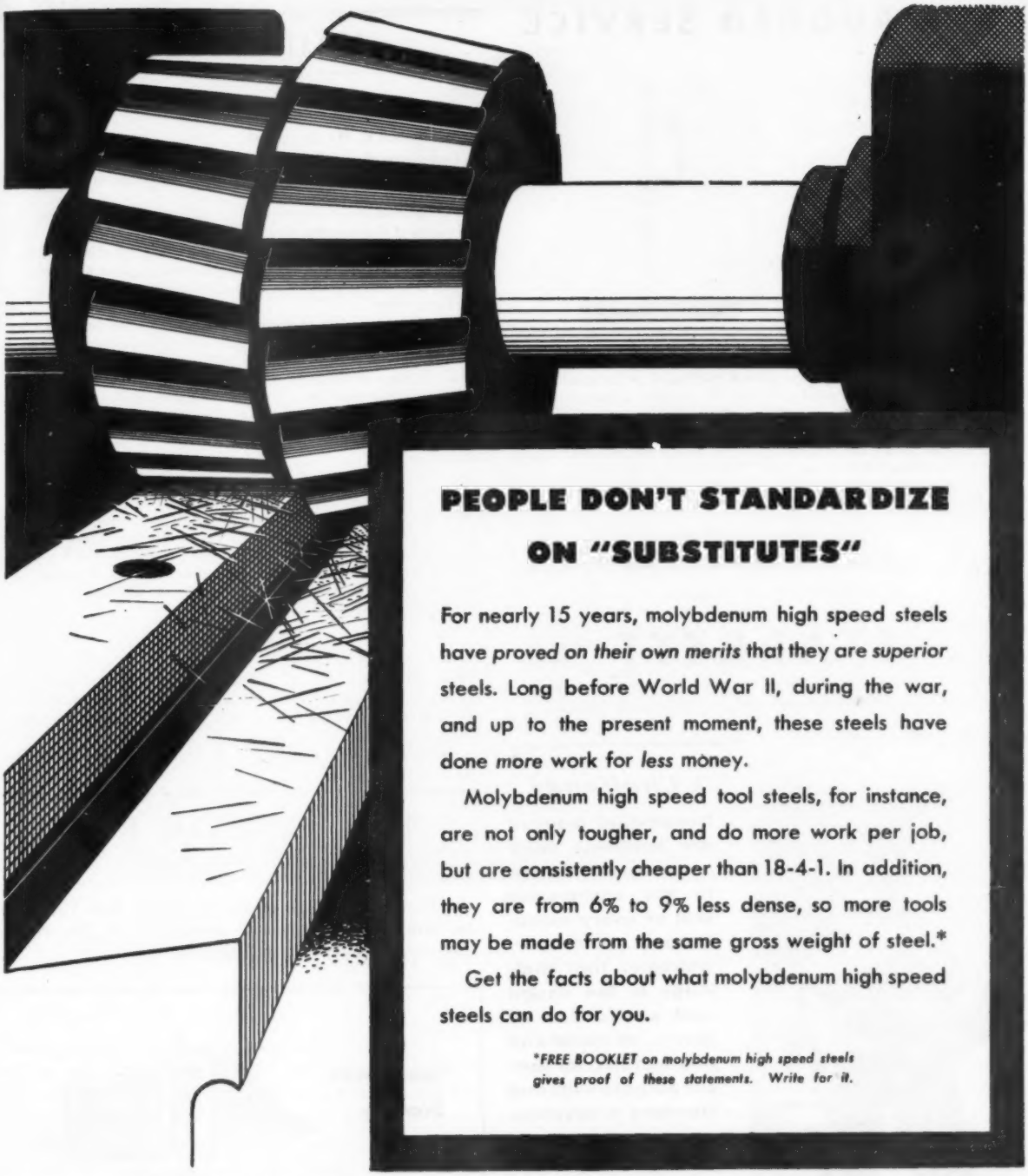
About Physics. — The Review takes pleasure in presenting (page 201) the second of the lectures in memory of Arthur D. Little, '85, entitled "Physics in the Contemporary World" by J. Robert Oppenheimer, Director of the Institute for Advanced Study, Princeton, N. J. After receiving the A.B. degree from Harvard University in 1925, Dr. Oppenheimer studied at Cambridge University and Göttingen University, the latter of which conferred upon him the Ph.D. degree in 1927; he was National Research Fellow in 1927–1928 and International Education Board Fellow in 1928–1929. From 1929 until he became director of the Los Alamos Laboratory of the Manhattan Project, Dr. Oppenheimer was professor of physics at the University of California and the California Institute of Technology.

Conservation for Engineers. — In the January issue of The Review, the basic concepts of conservation were developed by Dr. Ira N. Gabrielson, President of the Wildlife Management Institute. Already the ripple of last month's message is widening, as is indicated in Mail Returns, page 192. In his second article Dr. Gabrielson points out (page 205) the relationship between engineering and conservation. Dr. Gabrielson has spent his entire professional life in studying and directing research on wild life, game management, and in furthering this nation's efforts in the conservation of natural resources. His article "Relation of Conservation to Engineering Projects" is one of two lectures delivered to students in the Department of Civil Engineering last spring.

Student Prize Papers. — M.I.T. is universally known as providing outstanding training in scientific and engineering subjects; it is not so widely known for its program of humanities, intermural and intramural athletics, and self-governed student activities — all of which are aimed to make well-rounded individuals of its students. As an indication of ability of first- and second-year students to wield a pen, or typewriter — as well as a slide rule — The Review publishes, without editorial changes, two papers from last year's winners of the Robert A. Boit Prize for the "most effective use of English" in written papers. The Boit papers are "Evitability of World War III" by Frederic B. Krafft, '49, (page 210) and "The Limitations of Technique" by William S. Edgerly, '49, (page 211).

Professional Aid. — In "Bridges or Stepping Stones?" (page 212) Dugald C. Jackson, '21, examines the problem of help offered to younger men by engineers of established reputation and maturity. In so doing he is guided not alone by the fine example set by the elder Dugald C. Jackson who was for almost 30 years head of the Department of Electrical Engineering; he also draws upon his career as successful educator and administrator in several engineering institutions and upon more recent background as Army colonel in World War II. To a considerable extent, at present, Colonel Jackson's activities are taken up in directing

(*Concluded on page 192*)



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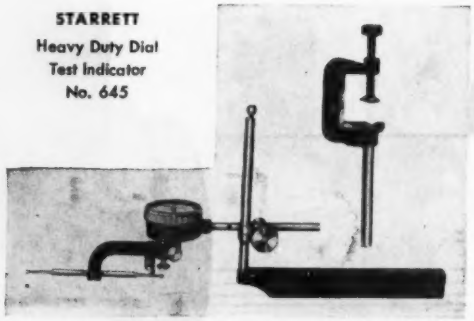

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MAIL RETURNS

Specialization — and Delay

FROM GEORGE R. WADLEIGH, '97:

Your cover on the December, 1947, issue of The Review interested me greatly, first because it is an interesting composition and second because of the sea wall design.

The location is not given but presumably is somewhere along one of the coasts of this country. The design is of a "new" type here, perhaps not over 20 years old. The very interesting point is that in Herculaneum 2,000 years ago this same design is to be found on a sea wall, the Bay of Naples then abutting the city. Now this wall is a quarter to a half mile from any water.

Two thousand years is no doubt longer than the time required at present for a good feature developed in one industry to spread into another, but our present intensive development of specialists is making for much delay in this respect.

It is apparent from Dr. Compton's talk here on December 9 that he and the Faculty are much alive to the question of overspecialization.
New York 18, N. Y.

Spreading the Word

FROM BENJAMIN P. RICHARDSON, JR., '26:

Dr. Ira N. Gabrielson's article "Concepts in Conservation of Land, Water, and Wild Life" in the January, 1948, Review was very interesting. If it is possible to obtain 200 copies of pages 149–153 I should be glad to spread the word to our junior club members. It might be another drop-on-the rock and prove productive to the cause.
Old Greenwich, Conn.

Pleasant Words

FROM JOHN A. ZUBLIN:

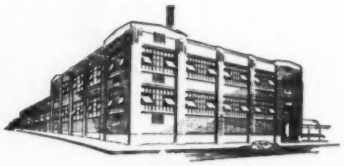
I am subscribing herewith to The Technology Review and enclosing my check. There is no need for you to send me this magazine on approval because if it is as good as M.I.T., then I want it and shall be anxious to read it.
Los Angeles 28, Calif.

THE TABULAR VIEW

(*Concluded from page 190*)

the Boston campaign of the American Red Cross, but he looks forward to early resumption of his work in engineering, industry, and education.

Speed with Economy



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Why housekeeping gets "lighter" all the time

"... Woman's work is never done."

True enough. But today's homemaker—aided by her modern refrigerator, range, water heater, vacuum cleaner and other appliances finds more time for family and for leisure.

And what helps these "automatic servants" operate so dependably? *Better materials* for one thing.

Materials on the inside—the unseen working parts of household standbys. Such as alloy steels, new plastics, carbon brushes in motors... lighter, more compact materials that make appliances stand up longer and handle with ease.

Materials, too, that you can see... as those stainless steel surfaces so easy to clean. Or the chemicals in more enduring waxes and polishes, varnishes and plastic finishes.

Yes, today's housewife enjoys new leisure, new freedom from drudgery... thanks to better materials.

Producing these better materials and many others—for the use of science and industry and the benefit of mankind —is the work of the people of UNION CARBIDE.

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Auto makers couldn't believe *any* tire could do what Goodyear's Super-Cushion does till they tested it themselves. Then they said:

"This tire makes a great improvement in the performance of the modern motor car. It's the biggest tire advance in 15 years!"

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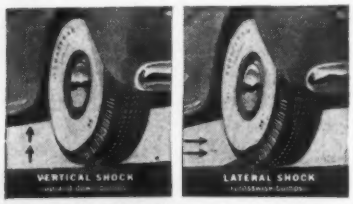
1. Softer ride—easier, safer car handling! The Super-Cushion is bigger and *softer*. It runs on *only 24 pounds* of air instead of 28 to 32.

You get a noticeably smoother, *softer* ride. And until you drive a car equipped with Super-Cushions, you can't imagine what ease and security they bring to car handling. Your car seems to *hug* the road, *flow* around turns!



2. Reduces rattles, cuts car repairs! *Till Goodyear designed the Super-Cushion, lateral shock was one of the few problems yet to be licked in modern motor cars.*

Pillowy Super-Cushions *soak up* these crosswise jolts, *soak up* vibration. *This means less driving fatigue, less wear on your car, fewer rattles, fewer bills—longer car life!*

3. Super-Cushions give greater mileage! Super-Cushions run cooler, build up less pressure. Because they're softer, they "roll with the punch," are harder to cut, bruise, or blow out.

Thus Super-Cushions consistently average more mileage than the finest standard tires!

Another Super-Cushion advantage: Because they're bigger, they improve the appearance of your car!

For the smoothest, safest ride you've ever had, more mileage and greater car economy, switch to Super-Cushions—whether your car is used or new. They'll make a big difference in its road performance. So see your Goodyear dealer now. If he doesn't have your size at the moment, he'll have it soon.

MORE PEOPLE RIDE ON GOODYEAR TIRES THAN ON ANY OTHER KIND

The new *Super-Cushion* by GOODYEAR

Super-Cushion T. M.—The Goodyear Tire & Rubber Company

VOL. 50 No. 4

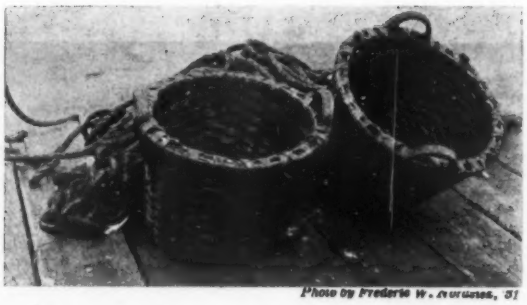


Photo by Frederic W. Peters, '51

THE TECHNOLOGY REVIEW

TITLE REGISTERED, U. S. PATENT OFFICE

EDITED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Editorial Associates: PAUL COHEN • T. L. DAVIS • J. R. KILLIAN, JR. • WILLY LEY • F. W. NORDSIEK
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Editorial Staff: THEODORA KEITH, RUTH KING *Business Staff:* MADELINE R. MCCORMICK

Published monthly from November to July inclusive on the twenty-seventh of the month preceding the date of issue, at 50 cents a copy. Annual subscription, $3.50; Canadian and foreign subscription, $4.00. Published for the Alumni Association of the M.I.T.: Raymond H. Blanchard, President; H. E. Lobdell, Executive Vice-president; C. George Dandrow, John A. Lunn, Vice-presidents; Charles E Locke, Secretary; Ralph T. Jope, Treasurer. Published at the Rumford Press, 10 Ferry Street, Concord, N. H. Editorial Office, Room 7-203, Massachusetts Institute of Technology, Cambridge 39, Mass. Entered as second-class mail matter at the post office at Concord, N. H. Copyright, 1948 by the Alumni Association of the Massachusetts Institute of Technology. Three weeks must be allowed to effect changes of address, for which both old and new addresses should be given.

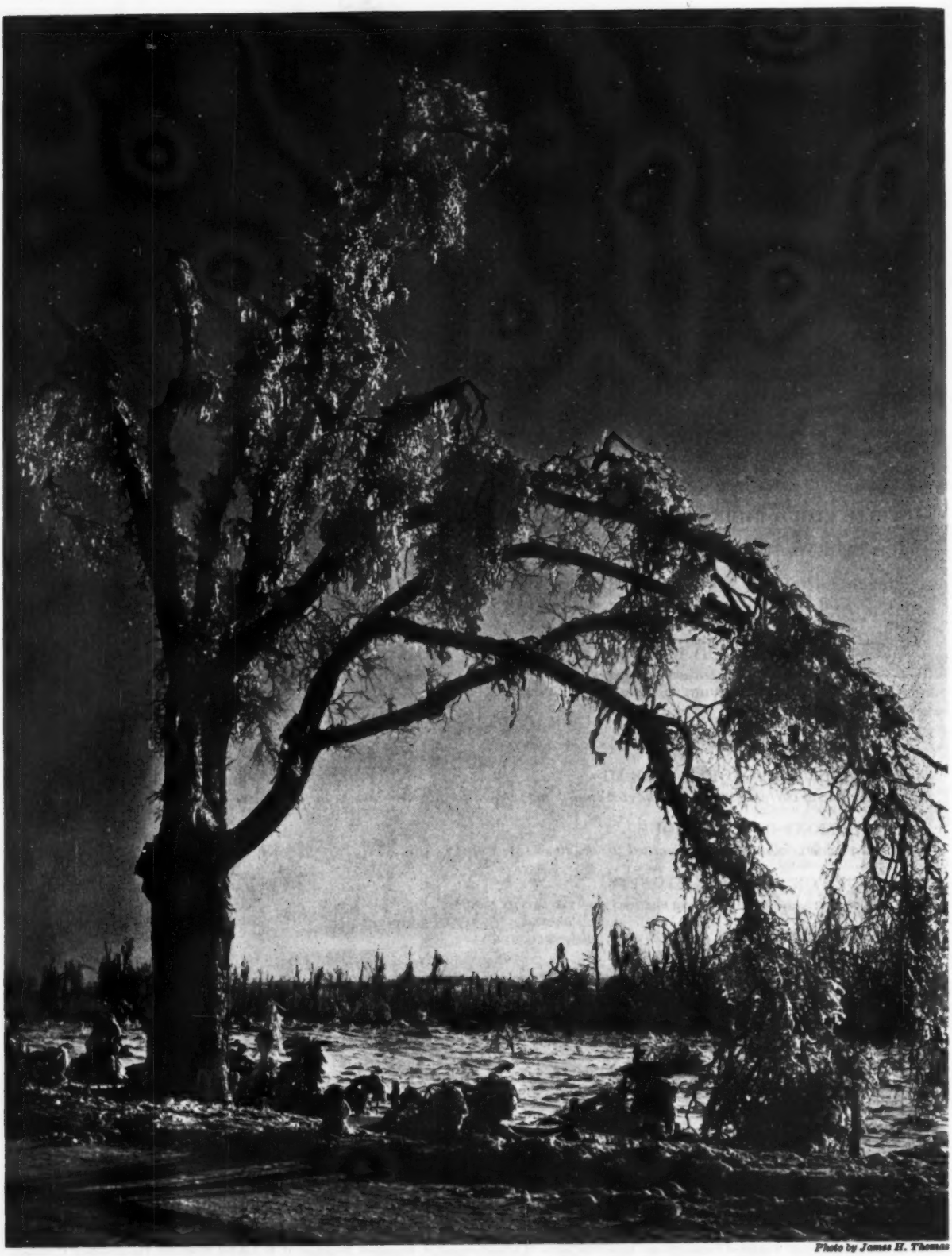


Photo by James H. Thomas

Ice Laden

THE
TECHNOLOGY
REVIEW

Vol. 50, No. 4

February, 1948

The Trend of Affairs

What Can't They Can?

FOR years all kinds of foods and many different beverages have been preserved in cans. Strangely enough the prime necessity of life, water, has only recently been canned with success, despite a long-standing need for such a product. Water is so bland that the slightest off-flavor or odor caused by a canning process is objectionable. Furthermore, colloidal metal salts in canned water may produce an unpleasant haze. Also, rusting is apt to occur, particularly after cans of water have been opened and partially used. An additional problem is created by the expansion of water when it freezes, so that cans in which water has frozen may rupture. A ramification of this difficulty arises from the tendency of canned water to supercool. If subjected to low temperatures in a state of complete rest, a can of water may form a hollow cake of ice containing a central core of water (liquid state) even though the temperature may be well below the freezing point. Since ice is bulkier than water, continued freezing from the outside creates a tremendous pressure upon the watery core. Eventually this pressure breaks the ice, thereupon releasing a jet of supercooled water with a force that may be sufficient to pierce the can.

A need has always existed for an acceptable canned water for lifeboat rations and related uses, but only during World War II did this demand become sufficiently urgent to generate the necessary research. Such research made use at its inception of the beer can that was perfected a little more than a decade ago. Beer cans are made from decorated tin plate, and then, after assembly, are lacquered and coated on the inside with a special wax. Ultimately some standard cylindrical beer cans were used to can water for the armed forces, and a special rectangular can based on the same principles was also designed.

The next step was discovery of the fact that water rusts cans much more rapidly when at the neutral point, pH7, than when slightly on the alkaline side of neutrality. To find a palatable water with the desired hydrogen ion concentration was not easy, as most alkaline waters have unpleasant tastes. After wide search, however, a spring was finally located that yielded abundant quantities of a water of acceptable flavor and with a pH of 8.5 after its temporary hardness had been removed.

The process ultimately perfected for large-scale water canning began with boiling of the special spring water for 15 minutes to precipitate deposits accounting for the temporary hardness, filtering off the precipitate, and then cooling the water to the 145 degrees F. filling temperature. The cans were prepared by rinsing with tap water that had been sterilized by ultraviolet irradiation. After filling and capping, the cans were pasteurized at 140 degrees F. for 20 minutes, in order to assure absence of harmful micro-organisms. The cans were then cooled to 100 degrees F., dried, dipped in wax to protect the exterior against corrosion, marked, and packed.

The problem of expansion upon freezing was solved by underfilling; the cans had a capacity of 14.75 fluid ounces, but only 11 to 12 ounces of water were placed in each. No solution was developed for the difficulty of supercooling. But rupture of containers due to supercooling must have occurred rarely, at most, under the actual practical conditions of use of the canned water. The success of the process is demonstrated by the observation that although approximately 4,000,000 cans of water were packed for the armed forces during World War II, virtually no reports of ruptured cans were received. Yet many of the cans must have been frozen repeatedly because they were used in emergency seat packs of aircraft operating at the low temperatures of extremely high altitudes.

The canned water was found to be completely acceptable as late as two years after packing. Thus the manifold canned foods and beverages long available have now been rounded out by a good canned water.

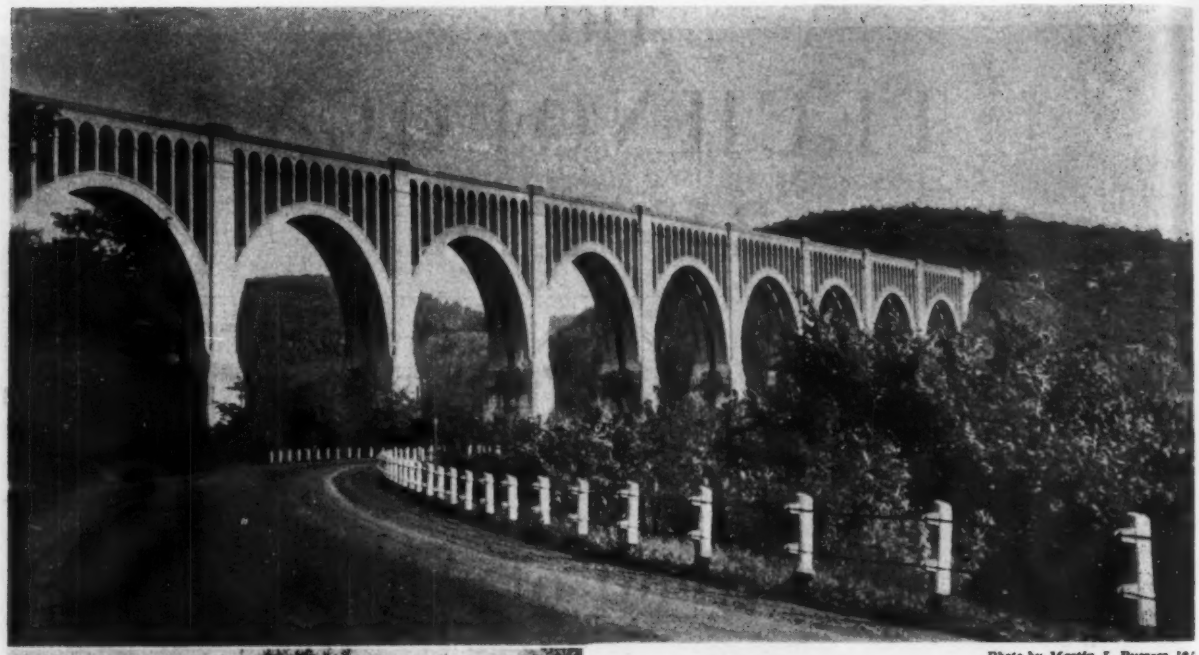


Photo by Martin J. Burger, '21

Graceful arches are incorporated in the design of the bridge on the Scranton-Binghamton Highway which, in many respects, bears a strong resemblance to aqueducts built centuries ago by Roman engineers and road builders.

Photo by William W. Lewis, '89

"Ole Man River" serves as one of the country's principal inland waterways but the unpretentious structure shown here, at the Itasca State Park in Minnesota, is reputed to be the first bridge built across the Mississippi.

Progress — of a Kind

ATTENTION is focused rather sharply upon this country's oil supply if for no other reason than that at the present time the health and comfort of many of the nation's citizens are threatened by shortage of fuel oil during a winter which promises to be — and already has been — unusually severe. Part of the national shortage may be attributed to the new and increased uses for petroleum which, in recent years, have outstripped production capacity. It is reported, for example, that the present annual demand for oil products is 20 billion gallons more than the prewar peak of 1941, and seven billion gallons more than was consumed during World War II when an all-time high was reached. The armed forces, trucks and busses, private automobiles, railroads, air lines, and ships, and oil burners for domestic heating — each group of which alone uses more than two and a half billion gallons beyond its 1941 requirements — account for the largest increase of petroleum uses in recent years.

The critical oil situation emphasizes the delicate balance of our technological mode of living, and the ease with which thoughtless and perhaps unresponsible acts on the part of a comparatively small group can affect adversely the comfort and health of a large portion of the nation's populace.

Strikes in the petroleum industry in Texas have left New England without fuel supplies adequate for assuring the maintenance of health, and have necessitated drawing upon government stocks. But work stoppages aggrevate the situation in still other ways. Certainly a substantial number of the million or more oil burners which have been put into operation since 1941 for domestic use must have been installed, at least partly, to achieve freedom from the tragic periodic strikes which have characterized the coal industry. The inability of petroleum producers to increase production capacity as rapidly as is needed to fill current requirements is laid to shortage of steel which, in turn, has been traced to strikes in the coal industry.

To the extent that one segment of our population feels it can profit by refusing to recognize the welfare of the country at large, it is possible, theoretically at least, to bridge the gap of man-made deficiencies. But it is also necessary to assess the situation in terms of known petroleum reserves as well as of increased use. "The disappearance of the reserve capacity to produce natural crude oil in the United States is the most important difference between this country's prewar and postwar economic and security situation," says W. C. Schroeder, Chief of the Office of Synthetic Liquid Fuels, Bureau of Mines. Kirtley F. Mather, Professor of Geology at Harvard University, has stated that our proved oil reserves will probably reach a maximum by 1950 and there-

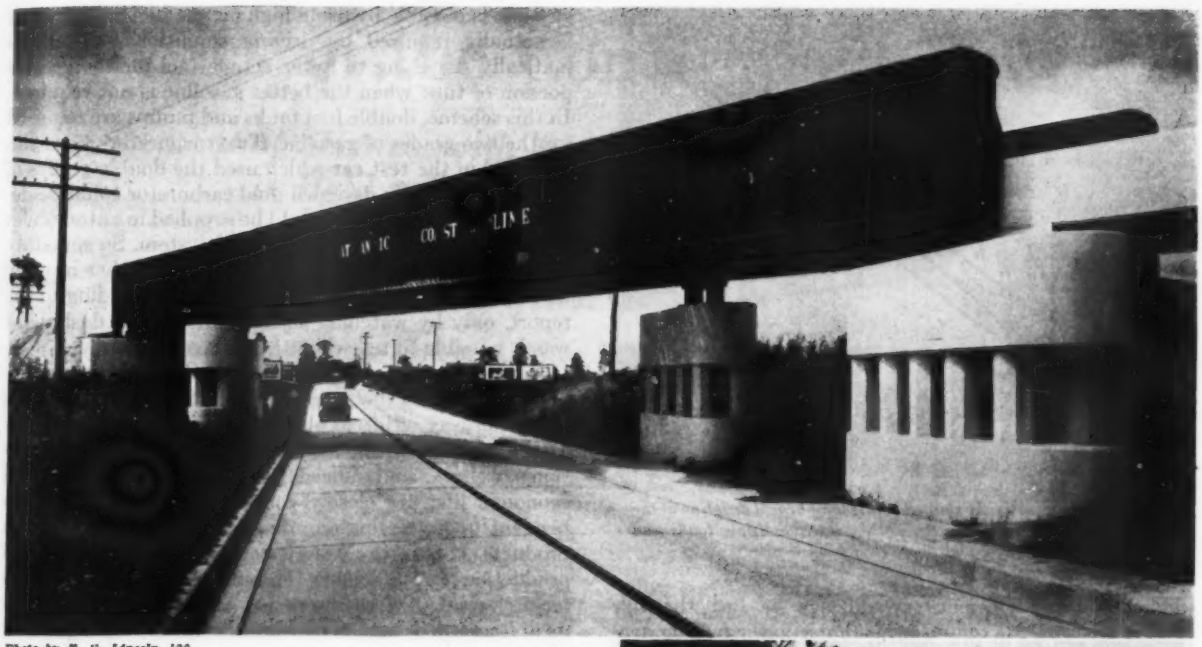


Photo by F. S. Lincoln, '22

Utilitarian design characterizes the railroad viaduct of the Atlantic Coast Line at Winter Park, Fla. Few structures typify the present technological era and our desire to travel better than such assemblies of steel and concrete.

Photo by Chester H. Pope, '09

Brathey Bridge, in the Lake Windermere district of England, reflects not only the calm and tranquil serenity of the English countryside in summer but the stoutness of its builders as well.

after "will descend toward zero." He says it is probable that domestic production will fail to meet needs within five or ten years from now.

One indication of the impending scarcity of oil reserves is the trend toward offshore drilling, since the continental shelves are about the only large areas fringing the United States which have not yet been extensively probed for oil. Already, two wells have been completed in the Gulf of Mexico, one five miles and the other 30 miles off the shore of Louisiana. Of these, one was driven to a depth of 12,874 feet but turned out to be a dry hole. Borings at the other struck the crest of a salt dome and subsequent drilling at the same site has so far failed to produce oil in commercial quantities. Questions of ownership of offshore oil fields complicate operations which might expedite deliveries from new sources of supply.

Even though the long-term possibilities of domestic supply are not optimistic, there are as yet no grounds to call the situation critical. Oil reserves in other parts of the world, notably the Middle East, are enormous, and are available so long as political conditions permit and sea transportation is feasible. Geologists suggest that, of the oil-producing regions so far known, the two largest are the basins surrounding the Gulf of Mexico and the Caribbean in one case, and the Persian Gulf in the other. Both have similar and highly promising structures; thick layers of marine sediments interposed with heavy layers of porous sandstone and limestone. In addition to such naturally occurring deposits, the practicability of producing liquid fuels from coal and oil shales has been demonstrated, although oil obtained in this way costs more than that obtained from naturally occurring deposits. In the background is the promise that, at least in certain fields, the pressure on petroleum may be relieved by progress in the industrial utilization of atomic energy. In spite of these technical possibilities, however, it would appear that the incentives to economize in our use of petroleum products are slated to increase in intensity as time goes on.

Since the automobile is the largest single consumer of liquid fuels in the United States, it is particularly significant to recall two recent steps which have been taken in this country to increase the efficiency of gasoline engines. Last summer Charles F. Kettering described the performance of gasoline engines with compression ratios as great as 12.5. A six-cylinder engine with this compression ratio was installed in a conventional automobile, replacing a 1946 engine with a compression ratio of six and four-tenths. The high compression engine weighed no more than a stock motor, but it had to be built to standards established for Diesel engines in order that its

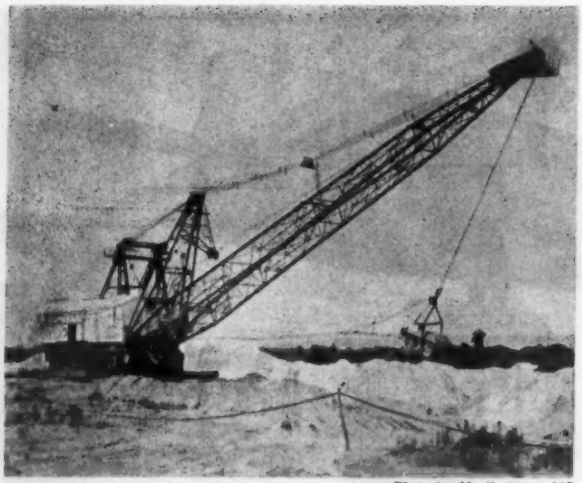


Photo by M. B. Crum, '25

Apparently precariously slanted is this long-armed dragline of the largest excavating shovel in the world while the dipper loads and unloads phosphate rock from a pit.

higher thermal efficiency would not be lost through higher friction. Maximum brake horsepower for the new engine was 95 as compared to 85 horsepower of the conventional engine which it replaced. The high compression engine reduced fuel consumption by approximately one-third, since 26.5 miles per gallon were obtained instead of the 18.5 miles per gallon for the car with the conventional stock motor. Because of the higher quality of fuel required, it is not likely that engines with compression ratios as high as 12 will be built immediately in large numbers. Nevertheless, it is interesting to observe that, so far as efficiency is concerned, the new engine represents about the same degree of progress over conventional engines as has already been accomplished in automotive engineering. In the last 30 years, compression ratios have increased from about four or four and a half, to about six and a half. With roughly a 50 per cent increase in compression ratio has come a saving in fuel consumption per brake horsepower of about 30 per cent. Concurrently have come improvements that have raised octane ratings from about 50 at the time of World War I * to about 70 or 80 for today's automotive fuels. To keep all these splendid advances in their proper perspective, however, it must be pointed out that during the same period, automobile registrations have increased from 6,150,000 in 1919 to more than 31,000,000 in 1945, with the United States making up about two-thirds of the world's motor vehicle registrations. During the same period, the horsepower rating of individual cars has increased two and a half to three times. The net result, of course, is a tremendous increase in the consumption of petroleum products for motor vehicles in the United States.

According to Socony-Vacuum laboratories, a car makes its maximum demand on the quality of fuel when accelerating or climbing hills, with the throttle wide open. Such operating conditions occur only about 10 per cent of the driving time. This observation provides a clue to another development which attempts to circumvent the expense and difficulty of fuel supply for high compression engines. Considerable economy in the use of premium gasoline is possible by using high octane fuel only when it is actually required by driving conditions, and automatically switching to lower octane fuel for the greater portion of time when the better gasoline is not required. In this scheme, double fuel tanks and pumps are required for the two grades of gasoline. Two carburetors were also provided in the test car which used the double grades of fuel but a specially designed dual carburetor could be designed and undoubtedly would be supplied in automobiles produced for use with the dual fuel system. So smoothly was the engine shifted from one fuel to another in early tests as driving conditions changed, that according to the report, only by watching signal lights on the dashboard was it possible to tell when the shift occurred.

Americans are no respecters of the *lebensraum* philosophy of European dictators, and certainly it is not in the American way of life to obtain material benefits selfishly at the expense of others. But it is evident that the nation's welfare, and indeed its entire technological and economic life, are closely connected with, and are dependent upon, having an adequate supply of petroleum products. It is in the American tradition to increase the production and efficiency of industrial operations and technological devices, however, and the two improvements recorded here represent the kind of progress in which we take pride.

Research in the West

ASIDE from independent studies by college professors, little research worthy of the name appears to have been done prior to about 1900. Industrial research made substantial progress shortly after World War I but for some years was regarded more as a luxury than as a necessity. At least such was the impression created during the depression of the 1930's when many a research worker was dismissed from employment instead of being urged to bend his talents to the creation of new knowledge which, in turn, would result in new products for sale. But World War II appears to have put research not only on a firm footing but to have projected it into the class of big business as well. Now, research is here to stay.

As might be expected, research institutions, such as Arthur D. Little, Inc. and the Battelle Memorial Institute, for example, are well entrenched in the northeast quarter of the United States, which represents the oldest part of the country, and are hosts to major industrial and manufacturing projects. But the East has no monopoly on research. Armour Research Foundation in Chicago, the Midwest Research Institute in Kansas City extend facilities for scientific investigation into the Middle West, and the South is served by the Southern Research Institute at Birmingham. But the West is no longer a frontier outpost where land may be had for the settling, and it, too, is finding the need for its own comparable organizations, and getting them. Latest research organization to come to our attention is the Stanford Research Institute at Stanford University, Calif.

Under the guidance of Dr. Carsten Steffens, (who was National Research Fellow at M.I.T. in 1934–1935) as Director of Laboratories, and William E. Rand, '33, Assistant Director, the Stanford Research Institute is the first industrial research institute in the West. It offers research in engineering, chemistry, biology, physics and mathematics, and industrial and social sciences.

* This figure is obviously a guess for no octane scale existed 30 years ago.

Physics in the Contemporary World

Advancement of Science, with Knowledge Imparted for Man's Benefit, is Held to be Responsibility of Scientists in Second Arthur D. Little Lecture

By J. Robert Oppenheimer

IF I have, even in the title of this address, sought to restrict its theme, that does not imply an overestimate of physics among the sciences, nor a too great myopia for these contemporary days. It is rather that I must take my starting point in the science in which I have lived and worked, and a time through which my colleagues and I are living.

Nevertheless, I shall be discussing a number of things which are quite general for the relations between science and civilization. For it would seem that in the ways of science, its practice, the peculiarities of its discipline and universality, there are patterns which in the past have somewhat altered, and in the future may greatly alter, all that we think about the world and how we manage to live in it. What I shall be able to say of this will not be rich in exhortation; for this is ground that I know how to tread only very lightly.

But that I should be speaking of such general and such difficult questions at all reflects in the first instance a good deal of self-consciousness on the part of physicists. This self-consciousness is in part a result of the highly critical traditions which have grown up in physics in the last half century, where we have been forced to become aware of what it is that we are doing. It reflects also the experiences of this century, which have shown in so poignant a way how much the applications of science determine our welfare and that of our fellows, and which have cast in doubt that traditional optimism, that confidence in progress, which have characterized Western culture since the Renaissance.

It is then about physics rather than of physics that I shall be speaking, and there is a great deal of difference. You know that when a student of physics makes his first acquaintance with the theory of atomic structure and of quanta, he must come to understand the rather deep and subtle notion which has turned out to be the clue to unraveling that whole domain of physical experience. This is the notion of complementarity, which recognizes that various ways of talking about physical experience may each have validity, and may each be necessary for the adequate description of the physical world, and may yet stand in a mutually exclusive relationship to each other, so that to a situation to which one applies, there may be no consistent possibility of applying the other. Teachers very often try to find illustrations, familiar from experience, for relationships of this kind; and one of the most apt is the exclusive relationship between the practicing of an art and the description of that practice. Both are a part of civilized life. But an analysis of what we do and the doing of it — these are hard to bed in the same bed.

As it did on everything else, the last war had a great and at least a temporarily disastrous effect on the prosecution of pure science. The demands of military technology in this country and in Britain, the equally overriding demands of the Resistance in much of Europe, distracted the physicists from their normal occupations, as they distracted most other men.

The Legacy of the War

We in this country, who take our wars rather spastically, perhaps witnessed a more total cessation of true professional activity in the field of physics, even in its training, than any other people. For in all the doings of war we, as a country, have been a little like the young physicist who went to Washington to work for the National Defense Research Committee in 1940. There he met his first civil service questionnaire, and came to the questions on drinking: "never, occasionally, habitually, to excess." He checked both "occasionally" and "to excess." So, in the past, we have taken war.

All over the world, whether because of the closing of universities, or the distractions of scientists called in one way or another to serve their countries, or because of devastation and terror and attrition, there was a great gap in physical science. It has been an exciting and an inspiring sight to watch the recovery: a recovery testifying to extraordinary vitality and vigor in this human activity. Today, barely two years after the end of hostilities, physics is booming.

One may have gained the impression that this boom derives primarily from the application of the new techniques developed during the war, such as the atomic reactor and microwave equipment; one may have gained the impression that in large part the flourishing of physics lies in exploitation of the eagerness of governments to promote it. These are indeed important factors. But they are only a small part of the story. Without in any way deprecating the great value of wartime technology, one nevertheless sees how much of what is today new knowledge can trace its origin directly, by an orderly yet imaginative extension, to the kind of things that physicists were doing in their laboratories and with their pencils almost a decade ago.

Let me try to give a little more substance to the physics that is booming. We are continuing the attempt to discover, to identify and characterize, and surely ultimately to order, our knowledge of what the elementary particles of physics really are. I need hardly say that in the course of this we are learning again how far our notion of elementarity, of what makes a particle elementary, is from the early atomic ideas of the Hindu and Greek atomists, or even from the chemical atomists of a century ago. We are finding out that what we are forced

to call elementary particles retain neither permanence nor identity, and they are elementary only in the sense that their properties cannot be understood by breaking them down into subcomponents. Almost every month has surprises for us in the findings about these particles. We are meeting new ones for which we are not prepared. We are learning how poorly we had identified the properties even of our old friends among them. We are seeing what a challenging job the ordering of this experience is likely to be, and what a strange world we must enter to find that order.

In penetrating into this world perhaps our sharpest tool in the past has been the observation of the phenomena of the cosmic rays in interaction with matter. But the next years will see an important methodological improvement, when the great program of ultrahigh energy accelerators begins to get under way. This program is itself one of the expensive parts of physics. It has been greatly subsidized by the government, primarily through the Atomic Energy Commission and the Office of Naval Research. It is a superlative example, of which one could find so many, of the repayment that technology makes to basic science, in providing means whereby our physical experience can be extended and enriched.

Another progress is the refinement of our knowledge of the behavior of electrons within atomic systems, a refinement which on the one hand is based on the microwave techniques, to the developments of which the Radiation Laboratory of M.I.T. made unique contributions, and which on the other hand has provided a newly vigorous criterion for the adequacy of our knowledge of the interactions of radiation and matter. Thus we are beginning to see in this field at least a partial resolution, and I am myself inclined to think rather more than that, of the paradoxes that have plagued the professional physical theorists for two decades.

A third advance in atomic physics is in the increasing understanding of those forces which give to atomic nuclei their great stability, and to their transmutations their great violence. It is the prevailing view that a true understanding of these forces may well not be separable from the ordering of our experience with regard to elementary particles, and that it may also turn on an extension to new fields of recent advances in electrodynamics.

Recovery of Physics

However this may be, all of us who are physicists by profession know that we are embarked on another great adventure of exploration and understanding, and count ourselves happy for that. In how far is this an account of physics in the United States only? In how far does it apply to other parts of the world, more seriously ravaged and more deeply disturbed by World War II? That question may have a somewhat complex answer, to the varied elements of which one may pay respectful attention.

In much of Europe and in Japan, that part of physics which does not rest on the availability of elaborate and radical new equipment is enjoying a recovery comparable to our own. The traditional close associations of workers in various countries make it just as difficult now to disentangle the contributions by nationality as it was in the past. But there can be little doubt that it is very much harder for a physicist in France, for instance, or the Low Countries, and very much more nearly impossible for him in Japan, to build a giant accelerator, than for the workers in this country.

Yet in those areas of the world where science has not merely been disturbed or arrested by war and by terror, but where terror and its official philosophy have, in a deep sense, corrupted its very foundations, even the traditional fraternity of scientists has not proved adequate protection against decay. It may not be clear to us in what way and to what extent the spirit of scientific inquiry may come to apply to matters not yet and perhaps never to be part of the domain of science; but that it does apply there is one very brutal indication. Tyranny, when it gets to be absolute, or when it tends so to become, finds it impossible to continue to live with science.

Even in the good ways of contemporary physics, we are reluctantly made aware of our dependence on things which lie outside our science. The experience of the war, for those who were called upon to serve the survival of their civilization through the Resistance, and for those who contributed more remotely, if far more decisively, by the development of new instruments and weapons of war, has left us with a legacy of concern. In these troubled times it is not likely that we shall be free of it altogether. Nor perhaps is it right that we should be.

Nowhere is this troubled sense of responsibility more acute, and surely nowhere has it been more prolix, than among those who participated in the development of atomic energy for military purposes. I should think that most historians would agree that other technical developments, notably radar, played a more decisive part in determining the outcome of this last war. But I doubt whether that participation would have of itself created the deep trouble and moral concern which so many of us who were physicists have felt, have voiced, and have

tried to get over feeling. It is not hard to understand why this should be so. The physics which played the decisive part in the development of the atomic bomb came straight out of our laboratories and our journals.

Despite the vision and the farseeing wisdom of our wartime heads of state, the physicists felt a peculiarly intimate responsibility for suggesting, for supporting, and in the end, in large measure, for achieving, the realization of atomic weapons. Nor can we forget that these weapons, as they were in fact used, dramatized so mercilessly the inhumanity and evil of modern war. In some sort of crude sense which no vulgarity, no humor, no overstatement can quite extinguish, the physicists have known sin; and this is a knowledge which they cannot lose.

Probably in giving expression to such feelings of concern most of us have belabored the influence of science on society through the medium of technology. This is natural, since the developments of the war years were almost exclusively technological, and since the participation of academic scientists forced them to be deeply aware of an activity of whose existence they had always known but which had been often remote from them.

When I was a student at Göttingen 20 years ago, there was a story current about the great mathematician Hilbert, who perhaps would have liked, had the world let him, to have thought of his science as something independent of worldly vicissitudes. Hilbert had a colleague, an equally eminent mathematician, Felix Klein, who was certainly aware, if not of the dependence of science generally on society, at least of the dependence of mathematics on the physical sciences which nourish it and give it application. Klein used to take some of his students to meet once a year with the engineers of the Technische Hochschule in Hannover. One year he was ill, and asked Hilbert to go in his stead, and urged him, in the little talk that he would give, to try to refute the then prevalent notion that there was a basic hostility between science and technology. Hilbert promised to do so; but when the time came a magnificent absent-mindedness led him instead to speak his own mind: "One hears a good deal nowadays of the hostility between science and technology. I don't think that is true, gentlemen. I am quite sure that it isn't true, gentlemen. It almost certainly isn't true. It really can't be true. They have nothing whatever to do with one another." Today the wars and the troubled times deny us the luxury of such absent-mindedness.

Responsibility of Scientists

The great testimony of history shows how often in fact the development of science has emerged in response to technological, and even economic needs, and how in the economy of social effort, science, even of the most abstract and recondite kind, pays for itself again and again in providing the basis for radically new technological developments. In fact, most people, when they think of science as a good thing, when they think of it as worthy of encouragement, when they are willing to see their governments spend substance upon it, when they greatly do honor to men who in science have attained some eminence, have in mind that the conditions of their life have been altered by just such technology, of which they may be reluctant to be deprived.

The debt of science to technology is just as great. Even the most abstract researches owe their very existence to things that have taken place quite outside of science, and with the primary purpose of altering and improving the conditions of man's life. As long as there is a healthy physics, this mutual fructification will surely continue. Out of its work there will come in the future, as so often in the past, and with an apparently chaotic unpredictability, things which will improve man's health, ease his labor, and divert and edify him. There will come things which, properly handled, will shorten his working day and take away the most burdensome part of his effort, which will enable him to communicate, to travel, and to have a wider choice both in the general question of how he is to spend his life, and in the specific question of how he is to spend an hour of his leisure. There is no need to belabor this point, nor its obverse — that out of science there will come, as there

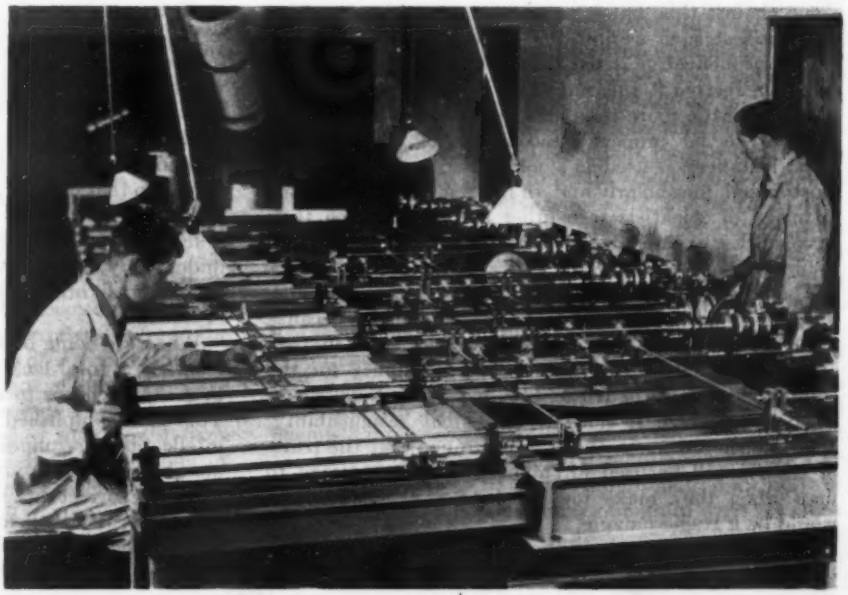


Photo by Dahlberg from Three Lions

Photo by Clarke from Black Star

has in this last war, a host of instruments of destruction which will facilitate that labor, even as they have facilitated all others.

But no scientist, no matter how aware he may be of these fruits of his science, cultivates his work, or refrains from it, because of arguments such as these. No scientist can hope to evaluate what his studies, his researches, his experiments may in the end produce for his fellow men, except in one respect: if they are sound, they will produce knowledge. And this deep complementarity between what may be conceived to be the social justification of science, and what is for the individual his compelling motive in its pursuit, makes us look for other answers to the question of the relation of science to society.

One of these is that the scientist should assume responsibility for the fruits of his work. I would not argue against this, but it must be clear to all of us how very modest such assumption of responsibility can be, how very ineffective it has been in the past, how necessarily ineffective it will surely be in the future. In fact, it appears little more than an exhortation to the man of learning to be properly uncomfortable; and, in the worst instances, is used as a sort of screen to justify the most casual, unscholarly and, in the last analysis, corrupt intrusion of scientists into other realms of which they have neither experience nor knowledge, nor the patience to obtain it.

The true responsibility of a scientist, as we all know, is to the integrity and vigor of his science. And because most scientists, like all men of learning, tend in part also to be teachers, they have a responsibility for the communication of the truths they have found. This is at least a collective if not an individual responsibility. That we should see in this any insurance that the fruits of science will be used for man's benefit, or denied to man when they make for his distress or destruction, would be a tragic naïveté.

There is another side of the coin. This is the question of whether there are elements in the way of life of the scientist which need not be restricted to the professional, and which have hope in them for bringing dignity and courage and serenity to other men. Science is not all of the life of reason; it is a part of it. As such, what can it mean to man?

Perhaps it would be well to emphasize that I am talking neither of wisdom, nor of an elite of scientists, but precisely of the kind of work and thought, of action and discipline, that makes up the everyday professional life of the scientist. It is not of any general insight into human affairs that I am talking. It is not the kind of thing we recognize in our greatest statesmen, after long service devoted to practical affairs and to the public interest. It is something very much more homely and robust than that. It has in it the kind of beauty that is inseparable from craftsmanship and form, but that has in it also the vigor which we rightly associate with the simple ordered lives of artisans or of farmers, that we rightly associate with lives to which limitations of scope, and traditional ways, have given robustness and structure.

The Discipline of Science

Even less would it be right to interpret the question of what there is in the ways of science which may be of general value to mankind in terms of the creation of an elite. The study of physics, and I think my colleagues in the other sciences will let me speak for them too, does not make philosopher-kings. It has not, until now, made kings. It almost never makes fit philosophers — or so rarely that they must be counted as exceptions. If the professional pursuit of science makes good scientists, if it makes men with a certain serenity in their lives, who yield perhaps a little more slowly than others to the natural corruptions of their time, it is doing a great deal, and all that we may rightly ask of it. For if Plato believed that in the study of geometry, a man might prepare himself for wisdom and responsibility in the world of men, it was precisely because he thought so hopefully that the understanding of men could be patterned after the understanding of geometry. If we believe that today, it is in a much more recondite sense, and a much more cautious one.

When then is the point? For one thing it is to describe some of the features of the professional life of the scientist, which make of it one of the great phenomena of the contemporary world. Here again, I would like to speak of physics; but I have enough friends in the other sciences to know how close their experience is to ours. And I know too that despite profound differences in method and technique, differences which surely are an appropriate reflection of the difference in the areas of the world under study, what I would say of physics will seem familiar to workers in other disparate fields, such as mathematics, or biology.

What are some of these points? There is, in the first instance, a total lack of authoritarianism, which is hard to comprehend or to admit unless one has lived with it. This is accomplished by one of the most exacting of intellectual disciplines. In physics the worker learns the possibility of error very early. He learns that there are ways to correct his mistakes; he learns the futility of trying to conceal them. For it is not a field in which error awaits death and subsequent generations for verdict: the next issue of the journals (*Continued on page 231*)

Relation of Conservation to Engineering Projects

Conservation Urged as Part of the Everyday Working Philosophy of Engineers

By Ira N. Gabrielson

EVERY engineering and development project affects land or water and wild life. That effect may be local and insignificant or it may be widespread and of major importance depending upon the character and the extent of the engineering development. For example, the construction of a highway has the immediate effect of taking out of vegetative production the actual strip on which the pavements are laid and thus to this extent it reduces the environment and food supply for wild life. That particular strip of land is also taken out of any potential agricultural or forest production. The construction of an airfield, the building of a city or a town and many other construction activities have similar direct results. In addition to the obvious direct effects, these projects may have surprising indirect effects upon the distribution and abundance of wild life, but they affect natural resources only locally and, from the point of view of the conservationist, are relatively insignificant. There are other engineering projects that have major effects upon the natural resources of large areas. The most important of such projects are drainage, impoundment of water, flood control, and the building of industrial plant and community sewage disposal facilities that empty their waste into streams and lakes. At times, such constructions have been very destructive of natural resources — often needlessly so. It is not those that have justified themselves but rather those of questionable long-time value, and those that have been proven to be mistakes, that we may use as object lessons. In an effort to avoid similar mistakes in the future, it might be well to discuss the effects on major conservation values of each type of project.

Drainage

Whether by ditching or by diversion of water, drainage of land has had a major effect upon the lands of North America. Approximately 100,000,000 acres of land have been drained by one method or another in the last 75 years. Such a radical alteration in the character of a large area cannot fail to have had profound consequences on the economy and upon the wild life and fish values of the communities affected. Some drainage projects have justified themselves in providing exceedingly rich agricultural lands yielding a greater value than could have been produced had the areas remained marshlands. A much larger percentage of drainage schemes are of questionable value. Some projects, resulting in the destruction of natural values, failed to yield the benefits anticipated from the drainage program.

Of the areas that could produce good agricultural land at a reasonable cost by drainage, most have already been drained. In the future, mistakes will be more easily made and will be much more costly than in the past. It is exceedingly important, therefore, to heed the lessons which previous mistakes teach.

A major result from the drainage already carried out and adverse to wild life has been the destruction of much breeding, feeding, and wintering grounds for the migratory waterfowl. Drainage has also destroyed much

breeding territory for aquatic and semiaquatic fur-bearing mammals and has, of course, completely eliminated the fish production in the drained areas. The lowering of water tables, sometimes a further adverse result of improper drainage, has made it more difficult to get local supplies of drinking water. The lowered water tables have reduced the productivity of the higher lands, particularly during the drought periods, and even in years of good rainfall have made it impossible to raise soil water levels sufficiently to produce maximum crops.

Millions of dollars of public funds have been spent in efforts to correct the errors and undo the destruction occasioned by many drainage projects. The mistakes most commonly made in drainage projects include failure to give proper consideration to fertility of soil of drained regions, careless or inadequate engineering, filling of marshlands for industrial sites, and indiscriminate drainage for mosquito control.

Marshes and lakes in which the underlying soil was of such a character as to be totally unproductive have often been drained. In at least some cases soil physicists and chemists informed the project developers in writing that the soils at the bottoms of these lakes and marshes were of a character as to be totally unproductive for agricultural purposes. Yet the drainage program went on. Such errors can be attributed to greed or selfishness rather than to ignorance.

There have also been cases of careless engineering in which very expensive drainage construction was completed before it was known that the gradient was too small to drain the land off rapidly enough to put in crops. For example, one drainage project in northern Minnesota was designed to provide 60,000 acres of farm land. A very extensive and expensive system of ditches through this marsh produced a total of 1,200 acres that could be cultivated even during the driest years. The remainder of the land was totally unproductive. After more than 30 years, the Fish and Wildlife Service purchased and reflooded the land. It is now producing a fine waterfowl breeding and feeding ground and is of growing value in the production of muskrats and fish. Another area of 22,000 acres in south-central Missouri was drained at great expense but only a small fraction of it was ever capable of producing crops. When the ditches were completed, it was found that the gradient was so low that the catch basin could not be emptied of ordinary rainfall fast enough to allow a crop in four seasons out of five. Considerable time will elapse before these two areas recover their primitive productiveness because of the necessity of restoring food and environmental conditions before maximum utilization and production of wild life can be expected. Yet this land, or rather water, is already producing substantial returns through conservation methods.

Such schemes speak only of incompetent or dishonest engineering. The only individuals who profited by these developments were the land speculators, the promoters and engineers who planned the projects, and the construction companies that built them. The landowners,

the community, and the nation lost by the destruction of an exceedingly productive area without the substitution of any value in its place. The Missouri area formerly provided a livelihood for many people by its fish, fur, and waterfowl production. At one time the swampy lake in the Missouri area was one of the most productive small freshwater fisheries of the country. The thousands of pounds of fish annually marketed assured a livelihood for a number of families. The yield of waterfowl and fur provided for still other families, all without public expense and without any attempt to improve production. This area is now being purchased for restoration and will eventually be returned to a productive state, but nothing can bring back the years of lost productivity.

Drainage and destruction of marsh and water areas have been carried out for other than agricultural purposes. For example, many acres of once productive marshes around San Francisco Bay have been filled in to obtain industrial sites.

The indiscriminate drainage for mosquito control purposes has been another source of the destruction of marshes, particularly of salt marshes. Some of these projects have been well engineered and effective, others have been neither. On the Atlantic Coast thousands of acres of marshes, ditched for mosquito control, are producing more mosquitoes than they did in their original state; in addition, their productive value has been greatly reduced or entirely destroyed.

Far from being wastelands, salt marshes are exceedingly important in producing fish and waterfowl food. They are the natural breeding place of much small animal life upon which waterfowl and the young of many important commercial fishes feed. By drying up salt marshes the environment of surrounding waters has often been altered to such extent as to destroy spawning grounds or reduce greatly the natural productive sources of food. Important waterfowl food beds in South Carolina and other coastal states have been completely destroyed without any compensating gain.

The destruction of much marshland was entirely needless. Repeatedly, it has been demonstrated that good results in mosquito control, without the destruction of other values, are obtainable through careful planning of drainage projects supported by some knowledge of ecological and biological factors. It is more and more important, therefore, that engineers have some knowledge of the over-all effects that may result from different types of engineering projects.

What is the Remedy?

The chief trouble has been in the basic philosophy of the businessmen and engineers who promoted drainage projects often in the mistaken belief that they were doing something beneficial for the community. It is a common idea that marshland is wasteland. Until men recover from this delusion, there is little hope that drainage projects will be proposed and constructed on a sound basis. Marshlands are not unproductive. Marshes are sometimes the spawning grounds for the best species of fish, and they are vitally important as wintering grounds for a large part of North America's waterfowl. Fresh-water marshes on the eastern shore of Maryland regularly produce greater net cash return per acre than the finest adjoining farm land. Each of hundreds of thousands of acres of coastal marsh along the Gulf Coast produce from 40 to 70 muskrats per year. When marshlands are properly managed and harvested, such returns can continue indefinitely. The management cost per acre is low; the principal expense being the actual trapping of the animals and the handling and marketing of the pelts.

Planning for future drainage of marshlands should take into consideration their present or potential productive capacity; the character of the soil and its value for agricultural use; the proportion of seasons in which it can reasonably be expected to produce agricultural crops

after the drainage program is complete; and the essential value of these lands in maintaining the North American waterfowl population which furnishes a major source of outdoor recreation and sport. Sometimes, because of its location, a marsh is valuable all out of proportion to the actual food produced, since it furnishes the only food and suitable resting place for the migratory flights for many, many miles along the flyway. This multiplies its actual value to many times the value of the food actually produced. If these permanent public values are realized and balanced against the potential productive value of the lands when drained, there will be far fewer drainage projects promoted and consummated in the future than there have been in the past.

Impoundments

At the present time major impoundments are usually built for one of three purposes: irrigation, hydroelectric power development, or flood control. In some cases two or more of these purposes are combined, yet impoundments for flood control differ so much from those for hydroelectric power that a reservoir can seldom be used for both purposes without sacrificing much of the value for one purpose or the other. An impoundment for irrigation cannot be used (except incidentally) for flood control or hydroelectric power if it is to perform completely its major function.

Irrigation developments may benefit or harm wild life. Irrigation impoundments have destroyed many valuable mountain lakes and streams without substituting equivalent wild-life habitat. Because of the nature and the season of the drawdown of reclamation projects it is exceedingly difficult to maintain wild life in or adjacent to impounded waters. Following impoundment there is usually a period of high productivity of fish, but as oxidation takes place and the early food production slumps, fishing goes with it. Reservoirs that fluctuate wildly, particularly during the spawning period and the growing season for aquatic plants, cannot be expected to be very productive of fish, of waterfowl food, or of foods for muskrats and other fur bearers.

Benefits to wild-life species can be increased greatly by incorporating appropriate conservation measures at the time the project is planned. A case in which a coordinated conservation and engineering program has been worked on from the beginning is the irrigation planned by use of water from the Grand Coulee Dam reservoir. When water is put on this land, it is certain to provide some benefits to waterfowl, and small upland game and fur bearers, a result which could not have been attained without a co-operative effort to get maximum values from all programs.

Photo by American Wildlife Institute

Land of the Navaho indians has been seriously eroded as a result of overgrazing. A spillway for a dam at the dry basin of Red Lake, north of Tuba City, Ariz., which is shown here under construction by Navahos, will benefit 30 nearby families.

The building of this dam cut the upper Columbia run of Chinook and blueback salmon from their spawning grounds. Coincident with the construction of the dam, a program of fish transplanting was carried out. As a result these species were successfully transferred to other streams that emptied into the Columbia below Grand Coulee Dam and which have not previously been used by salmon because of obstructions in the streams. These obstructions were removed or fish ladders built around them. The cost of the construction, the facilities for handling the fish, and the actual transplanting job was charged as a part of the construction cost of the project. This is as it should be as fish and other wild life are a public resource that deserve every consideration.

This principle is now embodied in the Federal law. Henceforth, no Federal agency can impound water without giving both the Federal Wildlife agency and the conservation agencies of the state in which the proposed work is located an opportunity to sit in on the planning, to evaluate its good or bad effects upon the fish and wild life, and to find means to offset any damage that may be found. In the case of certain proposed reclamation impoundments that might destroy existing wild-life refuge areas, agreements have already been reached whereby all such areas will be replaced by areas of equal productive capacity provided as part of the cost of the construction agency. This is a big step forward both in co-operation work and in public understanding.

Hydroelectric power impoundments usually provide the least values for wild life and do the most harm to fish and wild life of the streams on which they are located. The reservoirs are filled at flood times and drawn down at the time of greatest power demand. Their widely and wildly fluctuating water levels make it difficult, if not impossible, to develop a biological program on the impoundment. There are exceptions to this statement, but they usually trace back to accidents of climate and location. Good biological conditions can be and have been created in hydroelectric developments in which the upper ones of a series of dams are used only as reservoirs and downstream dams are used for maximum power production with water levels maintained relatively constant. As they have operated up to the present time, the Tennessee Valley Authority series of impoundments are a good example of this. Fishing has held up exceedingly well in the headwater reservoirs partly because the drawdown does not normally occur until after fish-spawning periods, but also because water levels are fairly constant well into the summer on the lower reservoirs. Generally, however, hydroelectric power impoundments are difficult to manage so as to protect or increase fish and wild-life populations because of the large water-level fluctuations and the rapidity of such changes.

Good fish-spawning areas and fine stands of waterfowl foods have been developed where it has been possible to cut off a narrow channel and protect the enclosed water area from the extreme fluctuations. In a few other areas where impoundment was not feasible or desirable, certain areas have been diked off and pumped dry. Crops of desirable waterfowl foods have been grown, and in the fall water was allowed to come into the dewatered area from the main reservoir. This scheme has been used successfully in areas of high malarial hazard to provide wintering grounds for waterfowl, as well as to guard against malaria mosquitoes. The water is returned to the area after the mosquito season is passed and pumped out again before the malaria mosquito period of the next season. By spreading a shallow layer of water over the area the ducks have ready access to an additional food supply without interfering with the primary purpose of the main impoundment.

Flood Control

Present engineering practices on flood control have probably provoked more controversy than any other single item of water management. An increasing number of soil physicists, soil conservation technicians, biologists, and limnologists are insisting that proper flood control does not consist only of huge dams and levees far down

on the lower reaches of a stream. They believe that these levees and the structures are at best of temporary value and that the permanent and logical way to reduce flood crests and to control them is to work first by using natural mechanisms to the limit before attempting to do the job by engineering devices. They believe that the first step toward proper control of flood waters is to install a system of proper land management that includes the control of water from the moment it falls to the ground. They believe that small ponds, proper terracing, contour plowing, strip cropping, and the similar devices of managing land to prevent destructive erosion, all practices that force water into the ground and insure the maximum possible amount of ground water storage, are the first elements in flood control. They believe that huge structures built on the main stems of the streams, without any accompanying effort to retard runoff from the land, are temporary and expensive ways of handling water.

To emphasize their point they call attention to the fact that such reservoirs silt up within a comparatively short time and become progressively more useless for flood control purposes. A great many of them silt up more rapidly than the calculations indicated at the time of their construction.

On the lower reaches of major streams such as the Mississippi, the levee system, built originally for the protection of cities and other important spots, has now been extended to cover many hundreds of miles of river bank. The levees are not only built bigger and higher as time goes on, but are crowded to the river as one area after another of the normal flood plane of the river is removed from that use by additional dikes. Consequently, the river is crowded into a narrower and narrower plane and channel. The inevitable result is that greater volumes of water and greater velocities must be dealt with so that flood crests frequently establish new records for high-water marks and property destruction. After all the hundreds of millions of dollars spent for flood control and navigation on two occasions in recent years the Ohio River has surpassed previous records for flood damage.

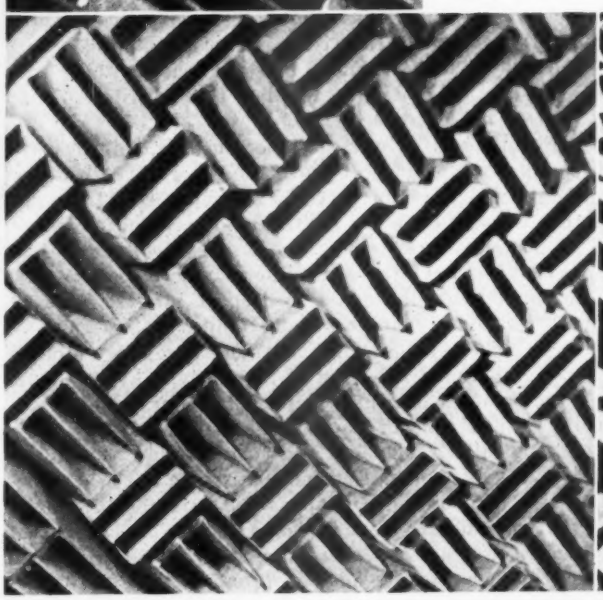
It is the growing belief of biologists and land managers that nearly all construction for flood control has been based on a mistaken premise. They contend that it is valuable for temporary use only, that the major effort and expenditure should be on the upstream control through the use of many small structures and by proper land and water management at the source of trouble. It is acknowledged that there will be fewer great dams built if such a program were to be followed, but there is growing understanding, and with it comes conviction, that the greatest good to the American people could come from the expenditures aimed at controlling flood waters, so far as possible, at the source. Instead of spending $25,000,000 or $30,000,000 for soil conservation and upstream water management, and $100,000,000 to $200,000,000 annually for massive dikes or dams on the main rivers, as has been the practice in recent years, they believe the program could be reversed, for a short time at least, with very substantial permanent benefits to the nation.

Conservationists have the greatest disagreement with the common engineering concept of controlling flood waters with massive dams and huge levees on the lower reaches of river drainage systems. The real need, however, is a basic understanding, on the part of the engineers, of the fundamental correlation of water and land management if the greatest good is to be obtained from both the water and land resources. (*Continued on page 218*)

Industrial Patterns

Examples of a few of the many interesting patterns of science, engineering, or industry are shown on this page. The views may be regarded as being slightly disguised since only portions of the originals are presented. Four of the five illustrations are of everyday subjects; the fifth is somewhat unusual.

Can you identify the subjects shown in the panels? Watch for next month's Review for answers.



Evitability of World War III

In Addition to the Technical Training which Students at M.I.T. Receive, Every Effort Is Also Made to Develop Their General Education

By Frederic B. Krafft

THE danger of a third World War does not lie in the far future. We are faced with the definite probability of war within a decade, unless exceptional statesmanship, supported by enlightened public opinion, can guide us through these next few years. Barring the remote possibility of a bacteriological revenge attack by Germany or Japan, or some disgruntled small nation, in the foreseeable future the only countries with the resources to wage full-scale warfare are the United States and the Union of Soviet Socialist Republics. It is the area of conflict between these two, fundamentally ideological, which must be contained and finally eliminated if war is to be avoided.

In this area of conflict, there are almost irresistible forces pushing the two nations and their satellites into war. Briefly, these forces are: the ideological differences between democracy, as we, in the United States, understand it, and communism, the disintegration of the British Empire, creating a power vacuum in certain strategic areas of the world, Russian political and geographic expansionism, which conflicts with American ideals of self-determination of peoples and ultimately threatens our security, and finally, economic disorganization and mounting pressures within Russia, which would be most easily quelled by the threat of an outside enemy.

If continued, the present patchwork method of attempting to solve the dilemma presented by Soviet ideological and geographic expansion and the increasing power vacuum in many parts of the world will lead eventually to war. It has become a truism to say that world power means world responsibility, but it is a truism that the people of the United States have not yet fully recognized. We face a world crisis. Only the United States has the power to effect a plan for permanent world peace. It has become our urgent responsibility to understand the possibilities of conflict and to formulate immediately a clear and consistent world policy that will give the world hope of the eventual elimination of those possibilities. The so called Truman Doctrine is not a world policy, although it can be a useful implement of such a policy. To insure peace, it must be integrated with other implements, within the framework of a continuing United States policy. The United Nations, which for the past two years we have wishfully tried to substitute for a foreign policy, is another such implement. An implement of tremendous potential usefulness, it is, for the present, immobilized by Russia's use of the veto.

To offer real hope of maintaining peace, United States world policy must provide both a short-range and a long-range program. The short-range plan has two weapons already in existence — the United Nations, which for the present is a moral force only, and the Truman Doctrine of economic and military aid to countries threatened by communist pressures.

To be immediately successful, and to give us time to work out the long-range plan for permanent peace, we must forge three additional weapons. First, we must sell our democratic ideals in the strategic areas of the world as Russia's propagandists attempt to sell the ideals of communism. Western ideas of political and individual freedom, government by majority, and a high standard of living for all, can *offer* as much as communist twaddle about a "dictatorship of the proletariat" and can give vastly more to the backward and war-devastated countries. It is in the realm of ideas in many of these areas that our greatest danger lies. As yet unprepared to wage another war, Russia is furthering her expansionist aims through political weapons, communist uprisings, guerrilla tactics, and political coup d'état. It is to counter this Soviet political weapon that the Truman Doctrine was developed. It needs the support of a democratic sales campaign to offset the infiltration of communist ideas and to nullify the charge of "American imperialism."

Another instrument in our immediate campaign to prevent war must be co-operation with Great Britain and France in the reconstruction of Europe, since Russian intransigeance blocks a Four Power settlement. We must also continue the closest possible collaboration, military and economic, with Great Britain. The British Empire is in the process of disintegration, but the British Commonwealth of Nations is still a potent influence in the world and provides vitally important bases and resources. Moreover, the Commonwealth is our next of kin, politically and culturally. The basic line of present Soviet strategy is to separate the United States and Great Britain. That strategy must not succeed.

Finally, and of utmost importance, is military preparedness. History will prove the theory that had the United States been prepared for war and warned the world that we would use our military and economic resources against any aggressor, neither Germany nor Japan would have risked war. Russia must be convinced that the new Truman Doctrine implies so deep an interest in world politics and welfare that any military aggression by Russia will be followed by full American military support to the victim. Unification of the Army, Navy, and Air Forces into an efficient Department of War, with particular emphasis on air power, universal military training, continued development and manufacture of atomic bombs, and all-out scientific research in the field of defensive and offensive weapons will persuade the Soviet that any military move would be suicide. To suggest that such a program of preparedness may provoke Russia to countermeasures is absurd. (*Continued on page 226*)

The Limitations of Technique

Presented Here Are Two Unedited Papers from First- and Second-Year Students, Submitted for the Robert A. Boit Prize to Stimulate Best Use of English

By William S. Edgerly

TO be a successful engineer, one must master certain techniques, certain details of procedure essential to expertness in handling the physical problems he will meet in his profession. This stress on techniques is strong not only in an engineering school, but in our highly industrial society as a whole. Due to this emphasis it is not surprising to observe the development of a materialistic trend in the modern mind, for such a trend will result from the application of the methods of the engineer to all of man's problem areas. The worship of technique is hardly understandable when one considers the many and varied problems that confront man in this complex world, many of which problems cannot be satisfactorily subjected to a purely materialistic analysis.

The training one receives in an engineering school, excluding the attempts at cultural broadening which are, at best, a side light, is aimed at the development of assorted skills which may be used in handling the problems of engineering and science. The physicist learns the mechanisms by which one kind of energy may be converted into another more useful form. The chemist is taught how to use chemical formulae and the molecular theory to create various substances. The major emphasis is necessarily on immediate methods to be used in solving specific problems; "necessarily" because the problems facing the engineer become increasingly complex with the advance of technology. More and more time must be spent in learning specific techniques, with the danger that the engineering school can afford to spend less and less time on other subjects of not so definite applicability in the engineer's work. The courses which are offered for the student's cultural development tend to be considered a waste of time by the student already burdened by his load of scientific courses. As a result of his forced preoccupation with technical subjects, the student is in danger of forming the habits of thought referred to by Philip Wylie in his *Essay on Morals* when he describes engineers as "imitators, that is to say: tinkers, not thinkers." [1]

Today's American hero is the engineer. We glory in "American ingenuity," in our mass-production economies and assembly-line techniques. Glowing words are written in praise of the doer as opposed to the talker — or thinker. Henry Ford, a hero of American industry, wrote, "With the changing wheel of ambition, boys no longer regard the talkative professions as more important than the manual . . . gigantic tasks . . . will be accomplished by doers rather than talkers." [2] And so it goes. Ours is a country where a premium is placed on results one can see. A man who can build a bridge, or turn out more shoes for less money, can add something tangible to the wealth of the nation. Why then should he not be entitled to praise and riches? And why should everyone not try to imitate his achievements? We boast of material progress and an improved standard of living. The car in every garage and the movie every Saturday night are the ultimate signs that America has achieved success. "For half a century . . . the articulate intellect of the West has been satisfied that the Grail will be found by the scientific method." [3] Our environment — practical, scientific, industrial America — is such as to make technique appear to be the *sine qua non* of all man's activities.

The popularity of the scientific method has led to the present prevalence of materialism. Especially among engineering students do we find contempt for the phases of human experience which cannot be handled by scientific techniques. A large number of science students have atheistic or agnostic tendencies. This seems no more than natural when one considers the success of the scientific method which is displayed daily to the engineering student in his courses of study and to the layman by the material riches created for him by science and engineering. When all things are reduced to the units of science and anything which cannot be reduced to those units is not conceded to exist, it is impossible to have other than a materialistic philosophy. For if every event can be explained on the basis of the action and reaction of atoms, if thought itself is nothing more than the stimulation or retardation of certain cells of the brain, where is there room for any inspiration, any divine guidance, or anything else which is intangible or immaterial? The extent to which this materialism is apt to run is indicated by the remarks of one student at M.I.T. who in all seriousness denied the existence of any moral or spiritual values in the world. He can conceive of no God that is not a natural force like the force of gravity or a physical entity made up of atoms and molecules. In his world, a world where, knowing the natural forces operating at any given time the only reasonable course of action one can follow is one which conforms to the direction of these forces, the concept of right and wrong has no significance. Hitler's treatment of the Jews was reasonable to him since it helped Hitler achieve the results he sought. When all is reduced to this materialistic interpretation, the problems of life seem extremely simple. The scientist's answer is always the one right solution. The age of reason is man's golden age. In the flush of this discovery Thomas Paine triumphantly announced his agnosticism. Robert Ingersoll was able to write in *Why Am I an Agnostic*, "In this mighty panorama of national (*Concluded on page 230*)

[1] New York: Rinehart and Company, 1947, p. 16.

[2] *My Philosophy of Industry* (New York: J. B. Lippincott Company's *American Issues* by Thorp, Curti, and Baker, 1944), p. 968.

[3] Wylie, *op. cit.*, p. 6.

Bridges or Stepping Stones?

In which Is Raised the Question of the Degree to which Youth Should Be Aided by the Experience of Mature Engineers

By Dugald C. Jackson, Jr.

THERE appeared in the bulletin of one of the well-known engineering societies a brief article entitled "Building Your Bridge." To the members of that engineering society the author suggested a realistic method of applying to their society activities the underlying thoughts of William Allen Dromgoole's familiar poem. Although the ideas expressed in that article are good, full consideration seems not to have been given to the thinking and actions of many engineers — from recent graduates to long-time leaders in the profession.

As Review readers will recall, Dromgoole's poem tells the story of an old man who having crossed a swollen stream with difficulty paused when on the other side to build a bridge to aid others — particularly young men — who might follow him. The editorial comment on this spirit of helpfulness was: "A fine philosophy — one which could be followed by some of our older and esteemed members of the engineering profession. They too should pause on the far side of a successful engineering career and lend a helping hand to the youth who soon will have to cross many chasms on the road to success."

Certainly we cannot take exception to the philosophy of the old man in the poem: Especially commendable is the matter of converting his academic philosophy of life into an active manner of living. Nor are the thoughts of the commentator to be decried. It is the peculiar obligation and opportunity of all engineers as professional men, particularly those with many years in the active practice of the profession, to extend a helping hand to the rising young engineers, the neophytes in the profession, by making available to them in a tangible and practical manner the lessons learned and the judgment gained from years of experience.

The one criticism of the poem and the comment on it concerns the amount of aid accorded the youth (the young engineer) rather than the method, and the implication by the commentator that "our older and esteemed members of the engineering profession" do not make a point of lending a helping hand.

Considering first the commentator's implication, let us answer the question: "Are the leading members of the engineering profession doing anything to assist the young engineers; are they building 'a bridge to span the tide'?" And again, "What proportion of the older engineers are extending a helping hand, and how long have they been doing it?"

The categorical answer to the last half of the second double-barreled question is: "More than 40 years." When he was president of the American Institute of Electrical Engineers in 1902–1903, the late Charles F. Scott with the support of T. Comerford Martin, Harris J. Ryan, and other leading engineers initiated local sections and student branches in the American Institute of Electrical Engineers for the benefit of less experienced engineers and even for students who had not yet entered the profession. Engineering matters, both past experiences and plans for the future, have been discussed at the meetings of the sections and branches ever since their establishment. In these meetings, leading members of the profession have set forth their experiences and expressed their opinions on engineering problems of import, to the great advantage of the young engineers and the engineering students who can afford neither the money nor the time to attend the national and regional conventions. At section meetings, also, young engineers have become personally acquainted with leaders in the profession, with resultant enhancement of their technical knowledge and enlargement of their professional perspective. Actions similar to those of the American Institute of Electrical Engineers have long been taken by all the major engineering societies.

Such activities for the benefit of the younger engineers undoubtedly could have been brought about and their development fostered by only a relatively few leading and influential engineers. Was this the case? The answer is an emphatic "No!" I cannot speak from personal knowledge of the period prior to the first World War, but let me draw upon my experience in the East, the Middle West, and the South since World War I.

Of the many engineers whom I met, I can remember none, with 10 or more years of professional experience, who was not genuinely interested in the problems and progress of the younger engineers and ready to advise and help them. Granted, many of these older men did not make an active effort to determine how they could best aid the young men, but relied on the latter to approach them for advice. Nevertheless, numerous young engineers benefited, through this passive form of assistance, from the advice and experience of older men. Moreover, besides those in education, a good 25 per cent of engineers, beyond 50 years in age, were devoting considerable time and thought toward making their experience available to younger men and toward encouraging other older men to do likewise.

The results of these efforts provide the answer to the first question we asked. Over the past 25 years various steps have been taken by the Founder Engineering Societies to implement in a practical way the helping-hand policy. One of these steps was the establishment, in the larger sections of the American Society of Mechanical Engineers, of subgroups composed of and run by the junior members with the advice, and assistance when desired, of some of the older experienced members. This provides an opportunity for the (*Continued on page 224*)

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

To Direct Athletics

MEMBERSHIP of the new Athletic Board, which succeeds the Alumni Advisory Council on Athletics as the advisory and policy-making body concerned with the Institute's athletic program, was recently announced by President Compton.

H. Guyford Stever, Assistant Professor of Aeronautical Engineering, has been appointed chairman of the board for a term of two years. The alumni members are William W. Garth, Jr., '36, and Lewis T. Jester, Jr., '41. The student body will be represented by William J. Hart, '48, Henry L. Henze, '49, and Duane D. Rodger, '48. The Faculty member, in addition to Professor Stever, is Professor Ronald H. Robnett, who will serve for three years. Ex Officiis members of the board are Dean Everett M. Baker, Dr. Dana L. Farnsworth, and Ivan J. Geiger.

In a letter to each member of the board, President Compton expressed his appreciation for their willingness to serve and outlined their duties. The appointment of Mr. Geiger as director of athletics, he pointed out, will permit the board to give the maximum amount of time to matters of policy.

The major functions of the new board will be to formulate policies to insure the most effective athletic program for the Institute's student body and to act in an advisory capacity to the President's Office and to the student management in matters affecting intercollegiate sports. The new board is expected to abide by the traditional Institute philosophy of encouragement of the maximum possible freedom of students in the management of their own affairs through their own system of student government. The board will act with power in the awarding of athletic letters and other awards and in the determination of eligibility to compete in intercollegiate sports. The athletic coaches will be responsible to the director of athletics under the general supervision of the Athletic Board. The Undergraduate Budget Board, of which Dean Baker is chairman, will be responsible for recommending the appointments, including salaries, of the athletic staff.

Honoraria

TWO members of the M.I.T. Faculty have been honored by the War Department for outstanding services performed during World War II.

William R. Hawthorne, '39, Associate Professor of Mechanical Engineering, who came from England to join the Institute's staff, was awarded the Medal of Freedom with bronze palm, the highest award within the power of the War Department to bestow on a civilian of a foreign country. The award was given for "very meritorious service in scientific research and development. An expert in the field of jet propulsion, gas turbines, and combustion, in the British Ministry of Aircraft Production, he did much to correlate British and American engineering efforts in that field and made available his own advice and counsel and the results of British research, greatly aiding the planning of American scientific programs." The medal was presented to Dr. Hawthorne by Colonel Harold R. Jackson, Head of the Department of Military Science and Tactics at M.I.T.

The Certificate of Merit, bearing the signature of President Truman, was awarded to Harold C. Weber, '18, Professor of Chemical Engineering, by Major General Alden H. Waitt, '14, of the Chemical Warfare Service. The certificate bore the citation: "for outstanding fidelity and meritorious conduct in aid of the war effort against the common enemies of the United States and its allies in World War II."

The presentations were made in the President's Office in the presence of Dr. Compton and members of the staffs of the recipients' Departments.

Alumni and Alumni-to-be

FRESHMEN numbering 37 who are sons of M.I.T. Alumni registered in the first-year class this fall. The Institute is especially proud of the occasion when an alumnus wishes his son to "come back to Tech" and doubly so when the son manifests his own wishes by enrollment at M.I.T. The listing follows:

Son	*Father*
Noel T. Adams	Frederick W. Adams, '21
Lee Brodsky	Saul Brodsky, '26
Ray C. Burrus, Jr.	Ray C. Burrus, '22
Zenas Crocker, 3d.	Zenas Crocker, Jr., '13
Philip M. Currier, Jr.	Philip M. Currier, '14
Foster P. Doane, 3d.	Foster P. Doane, Jr., '20
Bradford W. Edgerton	Earl M. Edgerton, '25
Herbert W. Eisenberg	Samuel S. Eisenberg, '15
Hasbrouck Fletcher	Ralph A. Fletcher, '16
Thomas R. Friedrich	Valentine Friedrich, Jr., '22
Ernest A. Grunsfeld, 3d.	Ernest A. Grunsfeld, Jr., '18
Robert L. Hardy	Arthur C. Hardy, '18
Richard S. Halsey	John C. Sweeney, '10 (deceased)
Myron A. Hoffman	Saul A. Hoffman, '16
Windsor H. Hunter	Frederick L. Hunter, '19
David A. Kallander	Ernest L. Kallander, '24
Thomas E. Kelly	Thomas P. Kelly, '18
John M. Lee	John G. Lee, '21
Harry N. Lowell	William P. Lowell, Jr., '26
Francis B. McKee	Andrew I. McKee, '21
Theodore A. Mangelsdorf, Jr.	Theodore A. Mangelsdorf, '26
Walter E. H. Massey, 2d.	Denton Massey, '24
John R. Myer	C. Randolph Myer, Jr., '22
Robert A. Norcross	Austin S. Norcross, '29
Peter J. Preston	Joseph K. Preston, '23
Bruce D. Replogle	Delbert E. Replogle, '24
John D. Robertson, Jr.	John D. Robertson, '16
Robert M. Rubin	Richard B. Rubin, '28
Arthur H. Schein	Sumner Schein, '21
David E. Schoeffel	Erwin G. Schoeffel, '23
Peter L. Silveston	Barnett Silveston, '27
Christen Smith	Gabriel Smith, '22
Paul G. Smith	Charles S. Smith, '22
Selden B. Spangler, Jr.	Selden B. Spangler, '32
Thomas A. Thornton	Charles E. Thornton, '21
Robert D. Thulman	Robert K. Thulman, '22
Donald R. Walton	James C. Walton, '23

At St. George's Bay, near Antigonish Harbor, Nova Scotia, the Crystal Farm (above) *has been selected headquarters for the new Institute of Geology, joint project of M.I.T. and the Department of Mines of Nova Scotia. Students from M.I.T. and the universities of Nova Scotia will find unusual opportunity for carrying out geological field studies while living in close contact with the instructing staff in delightful surroundings shown here.*

The long Central Hall on the main floor of Crystal Farm (above) *will be the center of recreational activities for students and Faculty members who have the good fortune to study geology at the new Institute of Geology. A corner of one of the main-floor living rooms is shown at the left.*

Photos by The Russell Studio

Geology Field Station

AIMING to broaden the scope for training and research in its field, an Institute of Geology has been established in Nova Scotia under the joint auspices of M.I.T. and the Nova Scotia Department of Mines. Arrangements for the co-operative project were completed recently by Premier Angus L. Macdonald of Nova Scotia and Walter L. Whitehead,'13, Associate Professor of Geology, representing Professor Warren J. Mead, Head of the Department of Geology at M.I.T., at a meeting attended by representatives of the Department of Mines, leading universities of Nova Scotia, and industrial concerns.

Headquarters of the new Institute, which is to open next summer, will be at Crystal Farm on St. George's Bay near Antigonish Harbor in Nova Scotia. The location for the Institute was selected because of the unusual advantages presented in that region for geological training, the variety of formations of structure being ideal for the instruction of undergraduates and graduate students in geology.

Under the new plan, members of the Faculty at M.I.T. will give Technology's required courses in summer field training in geology and associated sciences at the new field station. Students in geology from Nova Scotian universities will have the opportunity to join M.I.T. students in these courses, and students from other colleges of the maritime educational institutions and elsewhere will be considered if facilities permit.

The St. George's Bay region has historical association with the early development of geological sciences in Canada and the Maritime Provinces, and the classical sections described by Sir John William Dawson and other world famous pioneers in geology are nearby on the coast of Cape George near Arisaig.

The field training program this summer will be conducted by a group of professors from M.I.T. and from Nova Scotian universities, and it is expected that approximately 25 students will be registered for the program. The curriculum will cover a period of eight weeks, of which the latter part will be devoted to practical field mapping and more detailed studies related to the natural resources of Nova Scotia. This co-operative venture in a geological education was initiated by Professor Whitehead of M.I.T., Dr. Donald J. MacNeil of the University of St. Francis Xavier, and the Nova Scotia Research Foundation, and is sponsored by the Nova Scotia Department of Mines.

The Institute of Geology will be governed by a board, the members of which are expected to include the Honorable Malcolm Patterson, Minister of Mines for Nova Scotia; Professor Whitehead; Robert R. Shrock, Associate Professor of Geology at M.I.T.; Dr. MacNeil; Harold D. Smith, President of the Nova Scotia Research Foundation; Dr. G. Vibert Douglas and Dr. M. Bancroft, geological consultants; C. M. Anson, General Manager, Dominion Steel Company, and Harold Gordon, General Manager, Dominion Coal Company; and Robert D. Howland, Vice-president of the Nova Scotia Research Foundation.

The idea of summer studies by geological students in western Nova Scotia developed from work done during the past six years by two M.I.T. professors studying the petroleum reserves of the Acadian region. Cape Breton Island and the mainland from Canso Strait south to Cape George and Pictou were recognized to have almost every feature useful in teaching field geology to students. In this area, within a radius of 50 miles from the shore of

Photo by The Russell Studio

Meeting at Crystal Farm to form the Institute of Geology at which M.I.T. students and Faculty will study during the summer months are, in usual reading order, (first row): *Allan E. Cameron (hand on railing) President, Nova Scotia Technical College; Honorable Angus L. Macdonald, Premier of Nova Scotia; Walter L. Whitehead, '13, Associate Professor of Geology at M.I.T.; Harold D. Smith, President, Nova Scotia Research Foundation;* (second row): *Donald J. MacNeil, University of St. Francis Xavier; Robert D. Houland, Vice-president, Nova Scotia Research Foundation; Honorable Malcolm Patterson, Minister of Mines for Nova Scotia; C. M. Anson, General Manager, Dominion Steel Company;* (third row): *Harold Gordon, General Manager, Dominion Coal Company; and J. P. Messervey, Deputy Minister of Mines.*

St. George's Bay at Crystal Farm, is an assemblage of varied types of rocks ranging in age from extremely ancient formations to young deposits of the Glacial period. Mines and quarries are being worked in these rocks, several wells have been drilled for oil, the deepest to about a 12,000-foot depth, and many prospects for metals have been discovered. It is a region rich in both practical problems awaiting study and in traditional scientific interest.

Some of the earliest geological research in North America was done here. From 1843 to 1856, Sir John William Dawson made pioneer field studies later published in his monograph *Acadian Geology*. Much of his work was done along the shores of Northumberland Strait and on Cape Breton Island. The famous Joggins coal beds on the Bay of Fundy, where upright tree trunks are found in the coal with roots extending downward into shale, were described in 1845 by Sir William Logan, first director of the Geological Survey of Canada. Later William Barton Rogers, founder of M.I.T., visited this Nova Scotian area and wrote about its geology.

Dawson said: "The old and beautiful name Acadia . . . though it has a classic look and sound, is undoubtedly of aboriginal origin . . . and signifies . . . a place of plenty or abundance." His geological knowledge persuaded him that the natural mineral resources of Acadia, properly New Brunswick, Prince Edward Island, and Nova Scotia, had great value.

Crystal Farm is 650 acres in extent, with one-half mile on St. George's Bay. The house was built 80 years ago by the Crerar family and is well preserved. It is furnished suitably for its colonial style. Large breakfast, dining, and living rooms are adequate for the 30 students to be enrolled in 1948 and six large bedrooms are available for staff and visitors. A barn with hardwood floor 100 by 40 feet and great open fireplace provides an assembly room. Student sleeping quarters are to be in cottages now being erected. The Nova Scotia Department of Mines is arranging for a new water supply from springs above the house and for an electric power line to Crystal Farm.

The activities of the M.I.T. summer group will be intimately concerned with the study of these resources. The great coal mines extending under the sea at Sydney are 100 miles to the northeast of Crystal Farm. Those at New Glasgow and Pictou are 40 miles to the west. Other mines easily accessible are in the gold belt of eastern Nova Scotia and in gypsum-bearing beds.

An essential part of this joint project by M.I.T. and the Nova Scotian universities will be the geological study in detail of promising mineral and fuel deposits. Areas of interest will be suggested by the Nova Scotia Department of Mines and mapped by groups of students under close supervision by the Faculty members resident at Crystal Farm. The maps and reports will be a part of the governmental survey of the mineral resources of Nova Scotia. The nature of this work imposes real practical responsibility on students while in the field.

To Head Masonry Materials

APPOINTMENT of James S. Murray as Associate Professor of Materials in the Department of Building Engineering and Construction was announced recently by Professor Walter C. Voss,'32, Head of the Department. Professor Murray will take charge of the Masonry Materials Research Laboratory, in which fundamental research on cementitious materials and masonry units is being conducted.

Professor Murray, who is a native of Cambridge, Mass., has been associated with the Warner Company of Philadelphia as director of research since 1930. His research with this company concerned dolomitic and calcium lime products, sand and gravel, and central mixed concrete. In his capacity of director of research he gained wide experience in production problems in his field, as well as servicing and development problems.

Educated in the public schools of Somerville, Mass., Professor Murray was graduated from Harvard University in 1924 with the degree of bachelor of science in industrial chemistry. During the period from 1924 to 1926 he held technical positions with the Naugatuck Chemical Company, Naugatuck, Conn., the New Departure Manufacturing Company, Bristol, Conn., and M. W. Carr and Company of Somerville, Mass. In March, 1926, he joined the staff of the National Bureau of Standards in Washington, serving as a junior chemist in the lime and gypsum section of the building materials division. His work there led to his promotion to chief of his section. Here he gained valuable experience in the evaluation of plasters, mortar materials, and sand-lime brick to determine their conformity with Federal specifications. As section chief, he was a representative on the Federal Specifications Board. His studies of building materials have included investigations of the use of lime, cement, and gypsum on actual construction projects.

Professor Murray is a member of the American Society for Testing Materials, in which he has been very active, having served as vice-chairman of one of the Society's committees. He is also a member of the American Institute of Chemical Engineers and the American Chemical Society.

Approximately 600 Alumni and their wives attended the Compton Dinner Party given by The M.I.T. Club of New York at the Hotel Biltmore on December 9, when President Compton delivered an address on "Superior Education." At the head table, in reading order, are: Alfred L. Loomis, member of the Corporation; Mrs. Thomas C. Desmond; Raymond C. Rundlett, '22, President, The M.I.T. Club of New York; Mrs. C. George Dandrow; H. E. Lobdell, '17, Executive Vice-president of the Alumni Association; Mrs. Gordon S. Rentschler; Dr. Karl T. Compton, President of M.I.T.; C. George Dandrow, '22, Chairman of the Compton Dinner; Alfred P. Sloan, Jr., '95, member of the Corporation; Mrs. Karl T. Compton; Gerard Swope, '95, member of the Corporation; Mrs. Raymond C. Rundlett; Gordon S. Rentschler, member of the Corporation; and Senator Thomas C. Desmond, '09, member of the Corporation.

Figures and Machines

WIDELY recognized as an authority in his field, Zdenek Kopal has been appointed associate professor of computational analysis in the Department of Electrical Engineering.

A native of Czechoslovakia, where he was born in 1914, Professor Kopal holds the degree of doctor of science from Charles University, Prague. He was a research fellow at Harvard College Observatory from 1938 to 1940 and a research associate in astronomy in the University from 1940 to 1943. He has been a research associate at the Institute since 1946.

Following his graduation from Charles University, where he also served as a member of the faculty while carrying on work for his advanced degree, Dr. Kopal in 1938 was awarded the Ernest Denis Fellowship at the University of Cambridge, England, and worked for the first half of his fellowship year under the late Sir Arthur Eddington. It was while he was studying in England that he was invited by the director of the Harvard College Observatory to join the staff as Agassiz Research Fellow. He came to the United States in 1938 and in the summer of 1939 he served as a lecturer at the Harvard Summer Conference on Astronomy.

His association with the Institute began in 1942 when he joined the staff of the Center of Analysis. He is particularly interested in the development of large-scale computing machines and has been closely associated with advanced computation at the M.I.T. Center of Analysis.

Dr. Kopal is a member of the Royal Astronomical Society, the American Astronomical Society, the Astronomical Society of the Pacific, the Society of Sigma Xi, the International Astronomical Union, of which he is now an American representative. He is executive secretary of the Panel on the Orbits of Eclipsing Binaries of the American section of the International Astronomical Union.

Economics Award

PAUL A. SAMUELSON, Professor of Economics in the Department of Economics and Social Science, brought added honor to an already distinguished young career when he became the first winner of the John Bates Clark Silver Medal of the American Economic Association. The Clark Silver Medal is to be awarded approximately biennially to "that American economist under forty who is adjudged to have made the most significant contribution to economic thought and knowledge."

In making the presentation at the annual dinner of the American Economic Association in Chicago on December 28, Paul H. Douglas, President of the Association, cited Professor Samuelson for his "extraordinarily penetrating contributions to the theory of employment, production, distribution, and value."

At the age of 25 Dr. Samuelson became an assistant professor of economics and social science at M.I.T., and was promoted to associate professor in 1944. During this year he was granted leave of absence to serve as staff member of the Radiation Laboratory. Last July he was appointed professor of economics and social science. He is author of several books, including *Foundations of Economic Analysis** and *Economics: an Introductory Analysis.*†

* Cambridge, Mass.: Harvard University Press, 1947, $7.50.
† In publication.

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CONSERVATION AND ENGINEERING

(*Continued from page 208*)

Many engineers have not yet learned that any relation between the two exists. They need to learn that problems of water management and land management are inextricably interwoven. It is not possible for engineers to ignore the watershed behind the main rivers without ultimate disastrous results, both to their projects and to the nation. An increasing number of students of the problems believe that the overflow lands on the lower part of major rivers should be left as overflow lands for emergency use, and that the dikes should not be continually crowded closer to the river but should be moved farther back. The lands thus exposed to flooding are not wastelands as is popularly assumed. They produce quantities of fine timber, as well as fish and wild life in such abundance as to offset any additional agricultural value that may come by crowding the dikes closer to the river. The wider flood planes that remain furnish added protection to cities and towns farther down the river more cheaply, and much more certainly, than the continual multiplication of numerous engineering works for that purpose.

Stream straightening on slow, sluggish, very crooked streams may cause little interference with biological values. In fact, by creating additional oxbow lakes such operations have sometimes resulted in providing additional wild-life habitat. The straightening of streams with relatively steep gradient usually does damage to fish and wild-life habitat and populations. Straightening of such streams often produces a scouring action that quickly destroys fish-spawning beds and aquatic growth. It may also cause a lowering of the water table and produce an intermittent stream. Under such circumstances stream straightening often proves to be a two-edged tool that should be used with care and discretion if it is used at all.

Navigation

The building and operating of navigation channels in such rivers as the Mississippi and Missouri, is another controversial subject in which the conservationists and engineers do not always see eye to eye. A series of dams on the upper Mississippi above St. Louis is operated solely for the purpose of maintaining a nine-foot river channel with little or no regard to the effect which such operations may have on the fish and wild-life populations. The volume of freight hauled on most of these inland waterways has seldom justified the cost of constructing and maintaining the channel. When, in addition, there is taken into account the destruction of recreational, fur, fish and wild-life values, and the loss of timber or agricultural production of the lands flooded to maintain the channel, this type of water transportation becomes very expensive. A growing volume of public criticism can be expected until all values of our natural resources are taken into account in planning, constructing, and managing the water levels and operating the locks and dams.

(*Continued on page 220*)

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CONSERVATION AND ENGINEERING

(*Continued from page 218*)

Often the development of navigable channels has had somewhat unexpected results upon wild life. The construction of the intercoastal canal has brought salt water into many former fresh-water marshes with a resulting decrease in productivity. The damage varies from place to place, but it is fairly safe to generalize and say that the intrusion of salt water into a former fresh-water marsh decreases the productivity of that marsh by as much as one-half to two-thirds. In other words, as a salt marsh an acre of land will produce only from one-third to one-half of the food for waterfowl and fish which it produced as a fresh-water marsh. Development of the intercoastal canal has also impaired or destroyed locally important spawning grounds for shrimp, crabs and fish. At the time the canal was constructed no consideration was given to conservation measures. Much loss could have been avoided with little or no extra cost by appropriate planning in the early stages.

Pollution

Since the establishment of the first towns and the building of the first local industry in this country, it has been a common practice to dump untreated sewage and

industrial wastes into streams. When cities were small and industrial plants limited to small individual businesses, such undesirable practices mattered little. When cities grew so large that the volume of their wastes was greater than the stream could carry off and oxidize, domestic sewage became a problem from a biological standpoint. Pollution of streams by industrial wastes now has become a major problem of public health.

Pollution has been a major factor in decreasing the annual shad take and the harvest of other valuable fish in Atlantic coastal streams. It has been one factor in the decreased production of the Illinois River, once one of the major fresh-water fisheries in the country. These typical examples could be multiplied many times. Long conscious of the effects of pollutants on public health, citizens of this country have made vigorous efforts to control pollution that adversely affects health. These attempts have been only moderately successful since the volume of pollution has often grown faster than the curative measures.

It is only recently that the public has begun to understand the biological effects of pollutants. Public health and the prevention of moderate biological activity are two distinct and different things. Human or animal wastes, if unmixed with oil or chemical wastes, are not particularly harmful to biological production unless

(*Continued on page 222*)

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CONSERVATION AND ENGINEERING

(*Continued from page 220*)

they accumulate to a sufficient degree to utilize nearly all of the oxygen from the water. In fact, in moderate quantities they act as a fertilizer and increase the biological activity of the water. Conversely, human and animal wastes are particularly objectionable from a public health standpoint. On the other hand, many industrial wastes that may be present in quantities so small as to be unimportant to the public-health standard may easily be destructive to the aquatic biology. Industrial pollutants do not need to be present in sufficient volume to kill fish directly to destroy biological values. They can do so quite as effectively, if somewhat more slowly, if they prevent the growth of the small aquatic creatures that provide the basic food supply in the water.

Public interest is slowly becoming a force to compel remedial action by industries formerly reluctant to take corrective measures. A new group of specialists, including biochemists, chemists, physicists, and industrial engineers, are attempting to devise methods of handling pollutants other than by dumping them into the streams. Many of these efforts have already been successful but there is still much work to do in devising methods and means of getting them in use. Conservationists take the position that the only way to gain headway in reducing pollution is to stop immediately the building of new sources of pollution and then gradually to clean up the pollution that exists today. This conviction is based upon the experience over the past 40 years. During this period, particularly since 1930, considerable progress has been made as a result of the installation of several hundred community sewage disposal plants and a growing willingness on the part of major industries to install treatment units. World War II stopped most of this progress when it became impossible to secure either material or labor.

The war's demand for increased production caused the construction of many plants that emptied their wastes into waters that had not previously been seriously polluted. It concentrated human populations in areas where no adequate sewage treatment plants existed and overloaded hitherto adequate plants far beyond their capacity. In the opinion of many students of this problem, there is now more area of polluted water than ever before in the history of the country and the nation-wide condition has not improved.

As the population increases, the demand for food will increase. This will result in increasing public demand that the productivity of rivers be restored. Such a restoration job will take time, but both industrialists and prospective sanitary engineers can expect some such program to develop. To a conservationist there is little logical justification for the destruction of these public water values for the benefit of any industry no matter how important. It is not always, as is often asserted, a question of whether or not industry can exist, but whether or not greater or somewhat smaller profits can be made if adequate treatment facilities are provided for handling industrial effluents.

There is little logic in permitting the destruction of public waters used for recreational purposes, such as swimming, and then appropriating public money to build

(*Concluded on page 224*)

No. 6 — *Port Washington Station* — WISCONSIN ELECTRIC POWER COMPANY

When the Port Washington Station of the Milwaukee Electric Railway and Light Company (now Wisconsin Electric Power Company) went into service in 1935, its steam generating unit was the highest capacity, super-pressure boiler ever installed in a utility power station. It was as high as an eight-story building and as wide as a six-lane highway. Its drums, each forged from a single ingot, were sixty feet long with seamless walls five and a quarter inches thick, and each weighed seventy-five tons.

History-making as these figures seem, they merely highlight a more startling fact. This mammoth unit was, and is, the sole source of steam for an 80,000-kw turbine-generator. Thus Port Washington was the first large central station to go into service relying on a single boiler. The decision to place this confidence in the boiler resulted in a large initial saving in station cost and has been amply justified by the unit's record of reliability. In the eleven years since its installation, it has been available for service 95 per cent of the total elapsed time.

During 1936, its first full year of operation, Port Washington set a record for efficiency by operating at a lower average rate of coal consumption per kilowatt-hour than any other steam power station. Even more remarkable is the fact that today its overall station efficiency continues to be the standard by which steam station performance is measured.

In its expansion of recent years, Port Washington has recognized the fine performance of its original C-E boiler installation by placing repeat orders for three additional C-E Units. The first of these went into service in 1943, the second is about to go into operation and the third was ordered early this year.

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CONSERVATION AND ENGINEERING

(*Concluded from page 222*)

chlorinated swimming pools. There is little logic in shipping in supplies of fish and other aquatic food from a distance to replace those destroyed at home. There is no more logic in providing other expensive amusements to substitute for the lost fishing, boating, and other recreational opportunities. Certainly in assessing the value of a polluting industry, the cost of building and maintaining adequate supplies of water, clean enough for domestic and industrial use, and the cost of added public health services should be charged against the source of pollution before a balance sheet is struck.

In this article the critical attitude of conservationists toward many great engineering projects has been set forth. It can all be summed up in a few sentences. The basis of all criticisms is that little or no thought has been given to the basic natural resources in determining the necessity for, or the benefits to be expected from, a project, in determining the location of dams, levees, canals, and other waterway engineering structures, and in the operation of such projects upon completion.

Of course such criticisms will diminish as engineers broaden their interests and viewpoints beyond that required for the mere design of an engineering structure for a restricted and local area. Some engineers are already doing so. However, it is the view of many conservationists that the nation never will get full values for its huge expenditures for construction of water management projects until an understanding of the basic scientific principles of land and water management is a part of the everyday working philosophy of the engineers themselves.

It is a great satisfaction to see M.I.T. take a lead in introducing such information into its courses. I hope that the work will be successful and that the example will become contagious and spread rapidly to other engineering schools.

BRIDGES OR STEPPING STONES?

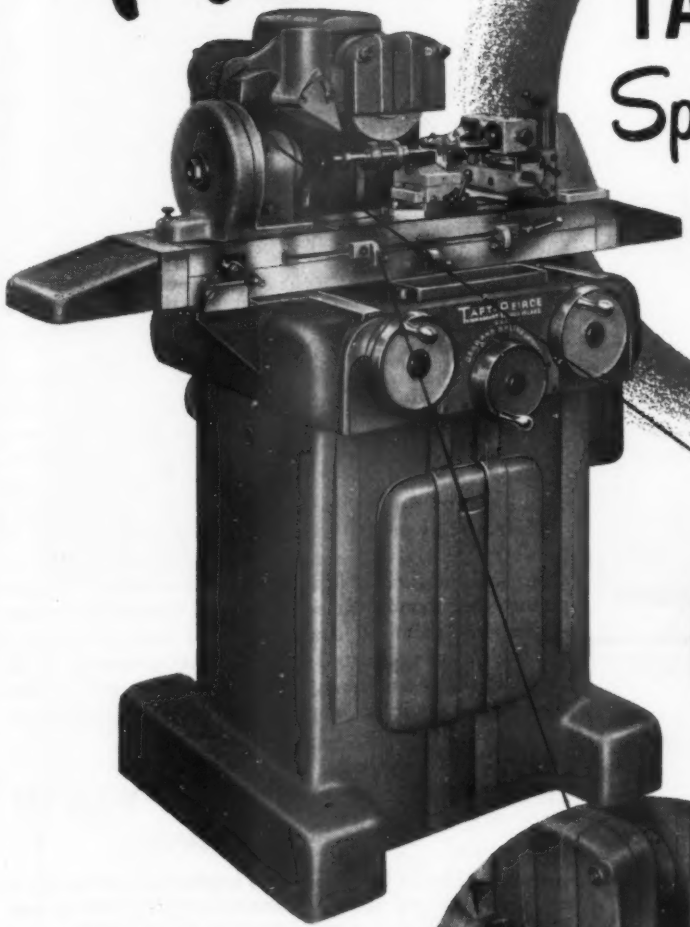
(*Continued from page 212*)

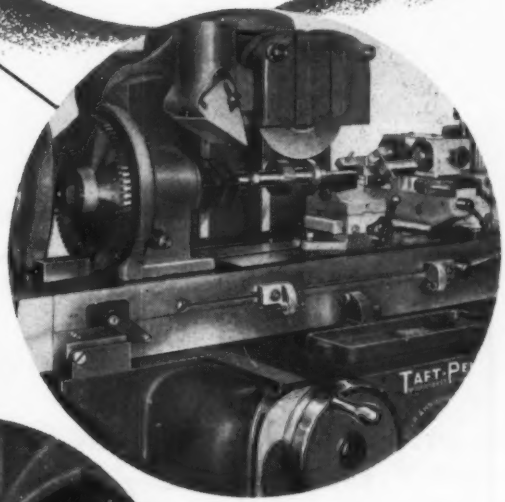
juniors to participate earlier in section activities and to use and profit more easily from the experience and counsel of older engineers, some of whom meet with them as advisers. The Engineers' Council for Professional Development, established in 1932, has been working steadily (though not as rapidly as some of the more impatient members of the profession would like) to aid the young engineer develop himself to professional status, particularly through its Committee on Professional Training. More recently the major engineering societies (particularly the American Society of Civil Engineers and the National Society of Professional Engineers) and many individual older and influential engineers successfully participated in efforts to alleviate the adverse effect of the Wagner Act on engineers, as the largest numbers affected by that Act were the young men. The result of their efforts was the inclusion in the Taft-Hartley Act of sections protecting the interests of all professional employees. These are three of numerous concrete evidences that individual engineers generally are giving active attention to the assistance of the younger men.

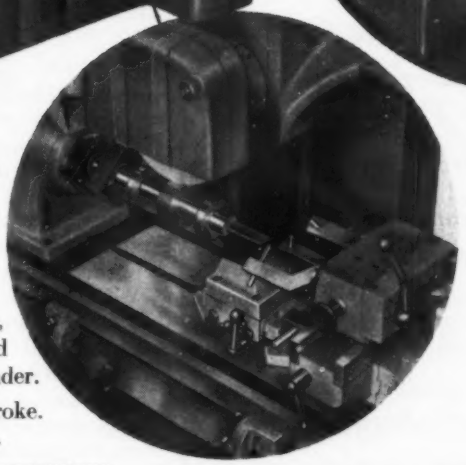
Now we come to the crux of the matter, the amount of

(*Concluded on page 226*)

New TAFT-PEIRCE Spline and Gear GRINDER







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▲ *Above:* Details of table, tailstock, and workhead construction, with index plate (uncovered) at left.

◀ *At Left:* Grinding a gear on the new Taft-Peirce Spline and Gear Grinder.

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BRIDGES OR STEPPING STONES?

(*Concluded from page 224*)

aid the older engineers should give to the younger men. Should the old man in the poem have built a complete bridge, or should he merely have set markers so that the youth could cross with reasonable safety, though with effort?

By building the bridge, the old man denied the youth the opportunity to gain experience in crossing streams and chasms, which experience he would sorely need when the old man had ceased his travels. Since the old man, with less physical vigor than the youth but with more experience and sounder judgment, crossed safely, certainly the youth could have crossed the yawning chasm and swollen stream if the old man had set markers to guide him. Had the latter tarried awhile longer, delaying construction of the bridge, he could have given the youth the more valuable experience of building it himself with the advice and assistance of the old man who had greater experience in such matters.

Judgment is gained and capability of accomplishment is developed through experience — both personal experience and the study and analysis of other men's experience. Acquisition of judgment and capability by personal experience alone can be wasteful of time and money and even dangerous at times. Depending entirely upon one's observation of others' experience, however, is likely to produce even less successful results; it is like trying to swim with no further instruction than viewing a motion picture that demonstrates the several swimming strokes. A properly balanced combination of both methods of gaining experience, based upon the joint judgment of the young engineer and his supervisor or adviser, will produce the best results in developing capability and judgment.

EVITABILITY OF WORLD WAR III

(*Continued from page 210*)

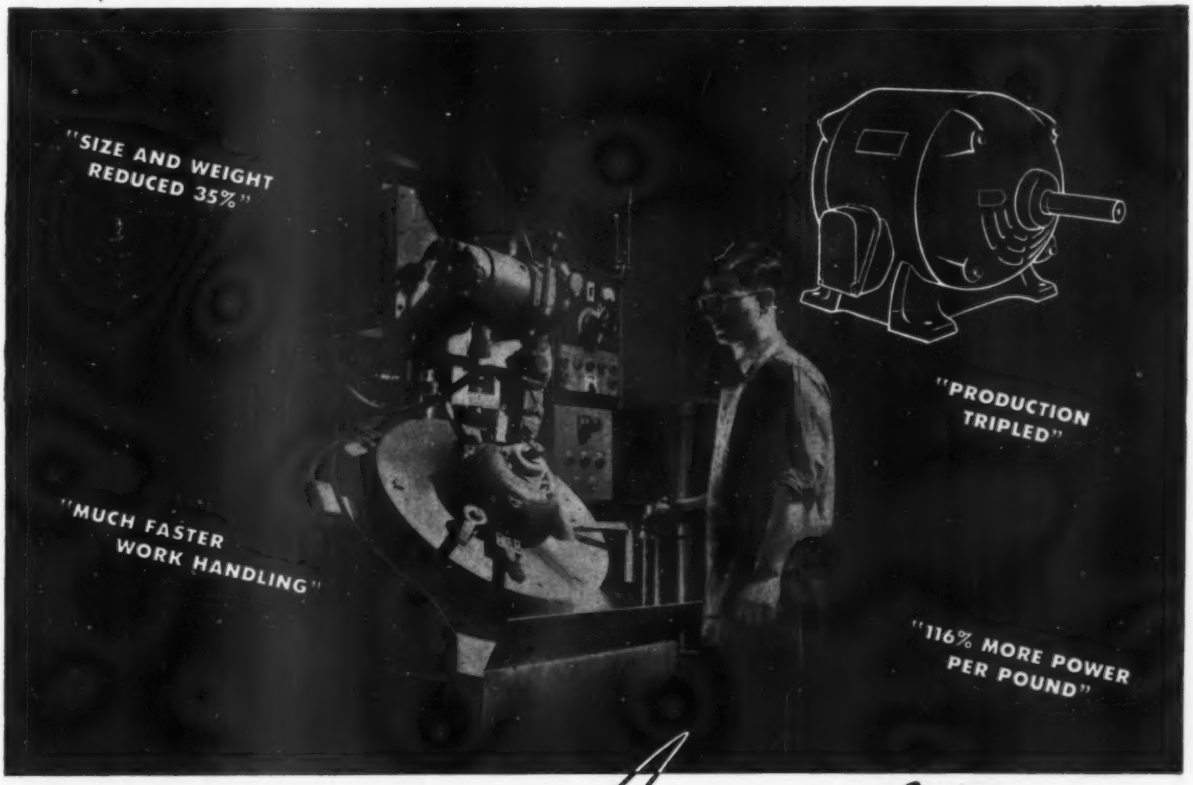
Russia is already following such a program as rapidly as her resources and rate of scientific progress will permit. Senator Vandenberg made the statement during the Senate debate on aid to Greece and Turkey that "we must choose the better calculated risk." The risk involved in military preparedness, in aid to Greece and Turkey, and in the rest of this short-range program in our world policy is far less than the risk of no action at all.

With these five weapons, the moral force of the United Nations, the Truman Doctrine, an intelligently planned and executed campaign to advertise the benefits of Western democracy, Three Power reconstruction of Europe, and a sound program of military preparedness, we can contain communism in its present boundaries and begin the gradual liberation of Soviet dominated areas in Europe and Asia.

This is the short-range plan. There is no alternative, other than continued appeasement of Russia — leading in the end to the communist-controlled world that the Soviet leaders have planned.

There are two possible long-range plans that, if effected, could insure the peace of the world. The first plan might easily grow from the Truman Doctrine if that newly

(*Concluded on page 228*)



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EVITABILITY OF WORLD WAR III

(Concluded from page 226)

formed policy is not integrated into a carefully formulated world policy. That plan is the economic and military domination of the world by the United States. Such a policy is alien to our traditions and ideals. Such a program would justify Mr. Wallace's charge of "ruthless imperialism." The regimentation necessary to achieve economic and military hegemony over the world would inevitably result in dictatorship. It is inconceivable that a plan to establish a Pax American would obtain the support of Congress or of public opinion.

The alternative long-term plan is the domination of the world, not by one nation, but by a world government. The most carefully formulated and documented program for world government is the Federal Union plan. Some adaptation of that principle must certainly be the final answer to the world-wide cry for permanent peace.

The Federal Union plan has the great advantage of immediacy. It can be begun simultaneously with the short-range plan we have discussed. The British Commonwealth of Nations and the United States can put it into almost immediate operation. The adherence of the democracies and quasi-democracies of Western Europe, the Middle East, China, India, and Latin America would soon follow the demonstration of the economic advantages of the Union. Only Russia and Soviet surrounded, and Soviet controlled, nations would remain aloof.

Would the inception of such a Federal Union plan by Great Britain and the United States provoke the Soviet Union to war? Not if our short-range weapons of military preparedness and economic and military aid to the nations on the Soviet perimeter are functioning. Such a Federal Union would soon have so tremendous an economic and military potential that the only alternative to membership for Russia and the nations in her orbit would be economic isolation. Such isolation would mean the end of Soviet Five-Year Plans and the progress in industrialization so necessary if Russian living standards are to be raised. Control, even in a police state, becomes impossible if the people are hungry and hopeless. They have nothing to lose by revolt, and everything to gain. It would mean the end of the Politburo dictatorship.

These two constructive programs, the immediate and the continuing, integrated into a single, complete United States world policy, and made clear to the world, could achieve not only "peace in our time," but peace for generations. While our short-range policy plugs the dike against the flood of communist ideology and Soviet expansion, we have perhaps 10 years in which to work out a successfully functioning Federal Union. At the end of that time, if we have failed, then we have the choice of accepting a communist dominated world, or fighting a third world war.

Nicholas Murray Butler, in a brief article titled "The Crisis," concludes, "We have come to the time when, if liberty is to be preserved and extended, its upholders and defenders must be prepared to lead the way to the next stage of political organization. The world is waiting for a new application of the federal principle." The world crisis can only be resolved by a Federal Union uniting the world into a vast new nation "conceived in liberty, and dedicated to the proposition that all men are created equal."

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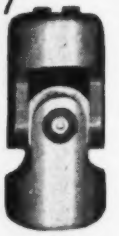

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LIMITATIONS OF TECHNIQUE

(*Concluded from page 211*)

life, reason has built and superstition destroyed . . ." [4] The Cult of Science is the breeding ground of materialism.

To say that all science necessarily leads to materialism would be an unfair generalization. It is only when science is thought to contain the ultimate explanation of all the questions which trouble man that it is the source of materialism. When the first flash of scientific achievement was passed and men began to delve deeper into ultimate causes, they began to realize that sooner or later scientists must reach a point beyond which lies the infinite unknown. As the theories of Einstein and Heisenberg delved deeper into the fundamental facts of the universe, it became clear that all was not so simple as the followers of Newton and Darwin at first supposed. Sir Arthur Eddington's "The Limitations of Physical Science" is a scientist's own expression of this feeling. He writes, "We recognize that the type of knowledge after which physics is striving is much too narrow and specialized to constitute a complete understanding of the environment of the human spirit." [5] Complete faith in the scientific interpretation of human experience represents an immature development in science. When I speak of the Cult of Science, I refer to that group which has not reached the maturity of thought demonstrated in "The Limitations of Physical Science."

Man's experience consists of two parts, the material and the spiritual. A materialistic philosophy, which is an attempt to reduce man's experience to the one material basis, is unsatisfactory because it is incomplete. The two aspects of experience should dovetail together, neither crowding out the other. The physical world is a part of our environment, and science or technique is the tool we use to shape that world according to our desires. But science looks only at the surface of things. It cannot get at the ultimate realities. When we know what the physical structure of the universe is from atom to sun, we will still ask, "What is it all about?" If we knew how to create a human organism by putting together the proper elements, we would still be unable to instill into it a moral consciousness, a sense of beauty, or any of the other attributes that make a man a man. If we try to analyze our religious experience with scientific principles, God is likely to become a mere personification of certain abstract principles. Beauty analyzed in a similar way becomes a compilation of data of physiological reactions. Is it sensible to eliminate them both for the sake of reason? "The truly human is found not in knowledge alone, but also in faith, in hope, in love, in puremindedness, in reverence, in the sense of beauty, in devoutness, in the thrill of awe, which Goethe says is the highest thing in man." [6] To assume that nothing is true which cannot be depicted in the models of the engineer or the symbols of the mathematician is to miss the most satisfying part of human experience. Modern science has come to realize that there are definite limitations to technique. When the "scientists" among us who still want to reduce everything to physical reality come to this realization, they will have caught up with a science.

[4] New York: J. B. Lippincott Company's *American Issues*, p. 808.

[5] *New Pathways in Science* (New York: The Macmillan Company, 1935), p. 309.

[6] Spalding, John Lancaster, *Means and Ends of Education* (New York: J. B. Lippincott Company's *American Issues*, p. 818.

PHYSICS IN THE CONTEMPORARY WORLD

(*Continued from page 204*)

will take care of it. The refinement of techniques for the prompt discovery of error serves as well as any other as a hallmark of what we mean by science.

In any case, it is an area of collective effort, in which there is a clear and well-defined community whose canons of taste and order simplify the life of the practitioner. It is a field in which the technique of experiment has given an almost perfect harmony to the balance between thought and action. In it we learn so frequently that we could almost become accustomed to it, how vast is the novelty of the world, and how much even the physical world transcends in delicacy and in balance the limits of man's prior imaginings. We learn that views may be useful and inspiriting although they are not complete. We come to have a great caution in all assertions of totality, of finality or absoluteness.

In this field quite ordinary men, using what are in the last analysis only the tools which are generally available in our society, manage to unfold for themselves and all others who wish to learn, the rich story of one aspect of the physical world, and of man's experience. We learn to throw away those instruments of action and those modes of description which are not appropriate to the reality we are trying to discern, and in this most painful discipline, find ourselves modest before the world.

The question which is so much in our mind is whether a comparable experience, a comparable discipline, a comparable community of interest, can in any way be available to mankind at large. I suppose that all the professional scientists together number some one one-hundredth of a per cent of the men of the world; even this will define rather generously what we mean by scientists. Scientists as professionals are, I suppose, rather sure to constitute a small part of our people.

Clearly, if we raise at all this question which I have raised, it must be in the hope that there are other areas of human experience that may be discovered or invented or cultivated, and to which the qualities which distinguish scientific life may be congenial and appropriate. It is natural that serious scientists, knowing of their own experience something of the quality of their profession, should just today be concerned about its possible extension. For it is a time when the destruction and the evil of the last quarter century make men everywhere eager to seek all that can contribute to their intellectual life, some of the order and freedom and purpose which we conceive the great days of the past to have. Of all intellectual activity, science alone has flourished in the last centuries, science alone has turned out to have the kind of universality among men which the times require. I shall be disputed in this; but it is near to truth.

If one looks at past history, one may derive some encouragement for the hope that science, as one of the forms of reason, will nourish all of its forms. One may note how integral the love and cultivation of science was with the whole awakening of the human spirit which characterized the Renaissance. Or one may look at the late Seventeenth and Eighteenth Centuries in France and England, and see what pleasure and what stimulation

(*Continued on page 232*)

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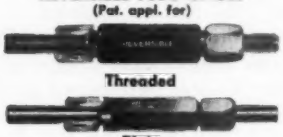

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PHYSICS IN THE CONTEMPORARY WORLD

(*Continued from page 231*)

the men of that time derived from the growth of physics, astronomy, and mathematics.

What perhaps characterizes these periods of the past, which we must be careful not to make more heroic because of their remoteness, was that there were many men who were able to combine in their own lives the activities of a scientist with activities of art and learning and politics, and were able to carry over from the one into the others this combination of courage and modesty which is the lesson that science always tries to teach to anyone who practices it.

And here we come to a point we touched earlier. It is very different to hear the results of science, as they may be descriptively or even analytically taught in a class or in a book or in the popular talk of the time; it is very different to hear these and to participate even in a modest way in the actual attainment of new knowledge. For it is just characteristic of all work in scientific fields that there is no authority to whom to refer, no one to give canon, no one to blame if the picture does not make sense.

Clearly these circumstances pose a question of great difficulty in the field of education. For if there is any truth in the views that I have outlined, there is all the difference in the world between hearing about science or its results, and sharing in the experience of the scientist himself and of that of the scientific community. We all know that an awareness of this, and an awareness of the value of science as method, rather than science as doctrine, underlies the practices of teaching to scientist and layman alike. For surely the whole notion of incorporating a laboratory in a high school or college is a deference to the belief that not only what the scientist finds, but how he finds it, is worth learning and teaching and worth living through.

Yet there is something fake about all this. No one who has had to do with elementary instruction can have escaped a sense of artificiality in the way in which students are led, by the calculations of their instructors, to follow paths which will tell them something about the physical world. Precisely that groping for what is the appropriate experiment, what are the appropriate terms in which to view subtle or complex phenomena, which are the substance of scientific effort, almost inevitably are distilled out of it by the natural patterns of pedagogy. The teaching of science to laymen is not wholly a loss; and here perhaps physics is a typically bad example. But surely they are rare men who, entering upon a life in which science plays no direct part, remember from their early courses in physics what science is like or what it is good for. The teaching of science is at its best when it is most like an apprenticeship.

James B. Conant, President of Harvard University, in his sensitive and thoughtful book, *On Understanding Science*,* has spoken at length of these matters. He is aware of how false it is to separate scientific theory from the groping, fumbling, tentative efforts which lead to it. He is aware that it is science as method and not as doctrine which we should try to teach. His basic sugges-

(*Continued on page 234*)

*New Haven, Conn.: Yale University Press, 1947. $2.00.

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PHYSICS IN THE CONTEMPORARY WORLD

(*Continued from page 232*)

tion is that we attempt to find, in the history of our sciences, stories which can be recreated in the instruction and experiment of the student, and which thus can enable him to see at first hand how error may give way to less error, confusion to less confusion, and bewilderment to insight.

The problem that President Conant has here presented is indeed a deep one. Yet he would be quite willing, I think, that I express skepticism that one can recreate the experience of science as an artifact. And he would no doubt share my concern that science so taught would be corrupt with antiquarianism. It was not antiquarianism, but a driving curiosity, that inspired in the men of the Renaissance their deep interest in classical culture.

For it is in fact difficult, almost to the point of impossibility, to recreate the climate of opinion in which substantial errors about the physical world, now no longer entertained, were not only held but were held unquestioned as part of the obvious mode of thinking about reality. It is most difficult to do because in all human thought only the tiniest fraction of our experience is in focus, and because to this focus a whole vast unanalyzed account of experience must be brought to bear. Thus I am inclined to think that with exceptions that I hope will be many, but fear will be few, the attempt to give the history of science as a living history will be far more difficult either than to tell of the knowledge that we hold today, or to write externally of that history as it may appear in the learned books. It could easily lead to a sort of exercise of mental inventiveness on the part of teachers and students alike which is the very opposite of the candor, the "no-holds-barred" rules of Professor Bridgman, that characterize scientific understanding at its best.

If I am troubled by President Conant's suggestions, this is not at all because I doubt that the suggestions he makes are desirable. I do have a deep doubt as to the extent to which they may be practical. There is something irreversible about acquiring knowledge; and the simulation of the search for it differs in a most profound way from the reality. In fact, it would seem that only those who had some firsthand experience in the acquisition of new knowledge in some disciplined field would be able truly to appreciate how great the science of the past has been, and would be able to measure those giant accomplishments against their own efforts to penetrate a few millimeters further into the darkness that surrounds them.

Thus it would seem at least doubtful that the spiritual fruits of science could be made generally available, either by the communication of its results, or by the study of its history, or by the necessarily somewhat artificial re-enactment of its procedures. Rather it would seem that there are general features of the scientists' work the direct experience of which in any context could contribute more to this end. All of us, I suppose, would list such features and find it hard to define the words which we found it necessary to use in our lists. But on a few, a common experience may enable us to talk in concert.

(*Continued on page 236*)

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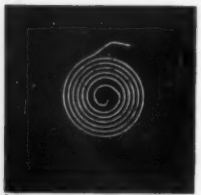
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PHYSICS IN THE CONTEMPORARY WORLD

(*Continued from page 234*)

In the first instance the work of science is co-operative; a scientist takes his colleagues as judges, competitors and collaborators. That does not mean, of course, that he loves his colleagues; but it gives him a way of living with them which would be not without its use in the contemporary world. The work of science is disciplined, in that its essential inventiveness is most of all dedicated to means for promptly revealing error. One may think of the rigors of mathematics, and the virtuosity of physical experiment as two examples. Science is disciplined in its rejection of questions that cannot be answered, and in its grinding pursuit of methods for answering all that can. Science is always limited, and is in a profound sense unmetaphysical, in that it necessarily bases itself upon the broad ground of common human experience, tries to refine it within narrow areas where progress seems possible and exploration fruitful. Science is novelty, and change. When it closes it dies. . . . . These qualities constitute a way of life which of course does not make wise men from foolish, or good men from wicked, but which has its beauty and which seems singularly suited to man's estate on earth.

If there is to be any advocacy at all in this talk it would be this: that we be very sensitive to all new possibilities of extending the techniques and the patterns of science into other areas of human experience. Even in saying this we must be aware how slow the past development of science has in fact been, how much error there has been, and how much in it that turned out to be contrary to intellectual health or honesty.

We become fully aware of the need for caution if we look for a moment at what are called the social problems of the day, and try to think what one could mean by approaching them in the scientific spirit, of trying to give substance, for example, to the feeling that a society that could develop atomic energy could also develop the means of controlling it. Surely the establishment of a secure peace is very much in all our minds. It is right that we try to bring reason to bear on an understanding of this problem; but for that there are available to us no equivalents of the experimental techniques of science. Errors of conception can remain undetected and even undefined. No means of appropriately narrowing the focus of thinking is known to us. Nor have we found good avenues for extending or deepening our experience that bears upon this problem. In short, almost all the preconditions of scientific activity are missing, and in

(*Concluded on page 238*)

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PHYSICS IN THE CONTEMPORARY WORLD

(*Concluded from page 236*)

this case, at least, one may have a melancholy certainty that man's inventiveness will not rapidly provide them. All that we have from science in facing such great questions is a memory of our professional life, which makes us somewhat skeptical of other people's assertions, somewhat critical of enthusiasms so difficult to define and to control.

Yet the past century has seen many valid and inspiriting examples for the extension of science to new domains. As even in the case of physics, the initial steps are always controversial; probably we should not as a group be unanimous in saying which of these extensions were hopeful, and which not, for the science of the future. But one feature which I cannot fail to regard as sound, particularly in the fields of biology and psychology, is that they provide an appropriate means of correlating understanding and action, and involve new experimental procedures in terms of which a new conceptual apparatus can be defined; above all, they give us means of detecting error. In fact, one of the features which must arouse our suspicion of the dogmas some of Freud's followers have built up on the initial brilliant works of Freud, is the tendency towards a self-sealing system, a system, that is, which has a way of almost automatically discounting evidence which might bear adversely on the doctrine. The whole point of science is to do just the opposite: to invite the detection of error and to welcome it. Some of you may think that in another field a comparable system has been developed by the recent followers of Marx.

Thus we may hope for an ever widening and more diverse field of application of science. But we must be aware how slowly these things develop, and how little their development is responsive to even the most desperate of man's needs. For me it is an open question, and yet not a trivial one, whether in a time necessarily limited by the threats of war and of chaos, these expanding areas in which the scientific spirit can flourish may yet contribute in a decisive way to man's rational life.

I have had to leave this essential question unanswered: I am not at all proud of that. In lieu of apology perhaps I may tell a story of another lecturer, speaking at Harvard, a few miles from here, two decades ago. Bertrand Russell had given a talk on the then new quantum mechanics, of whose wonders he was most appreciative. He spoke hard and earnestly in the New Lecture Hall. And when he was done, Professor Whitehead, who presided, thanked him for his efforts, and not least for "leaving the vast darkness of the subject unobscured."

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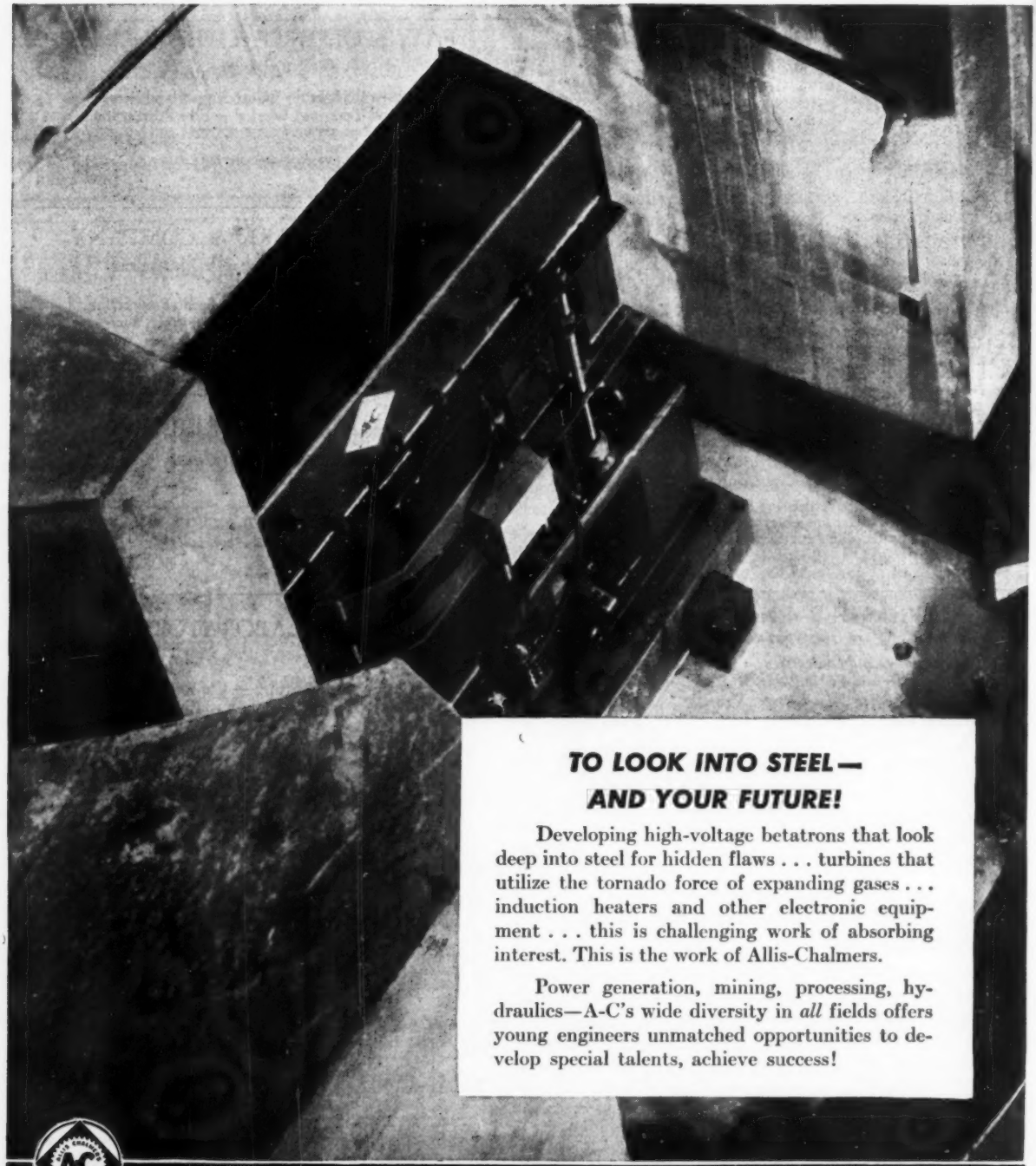

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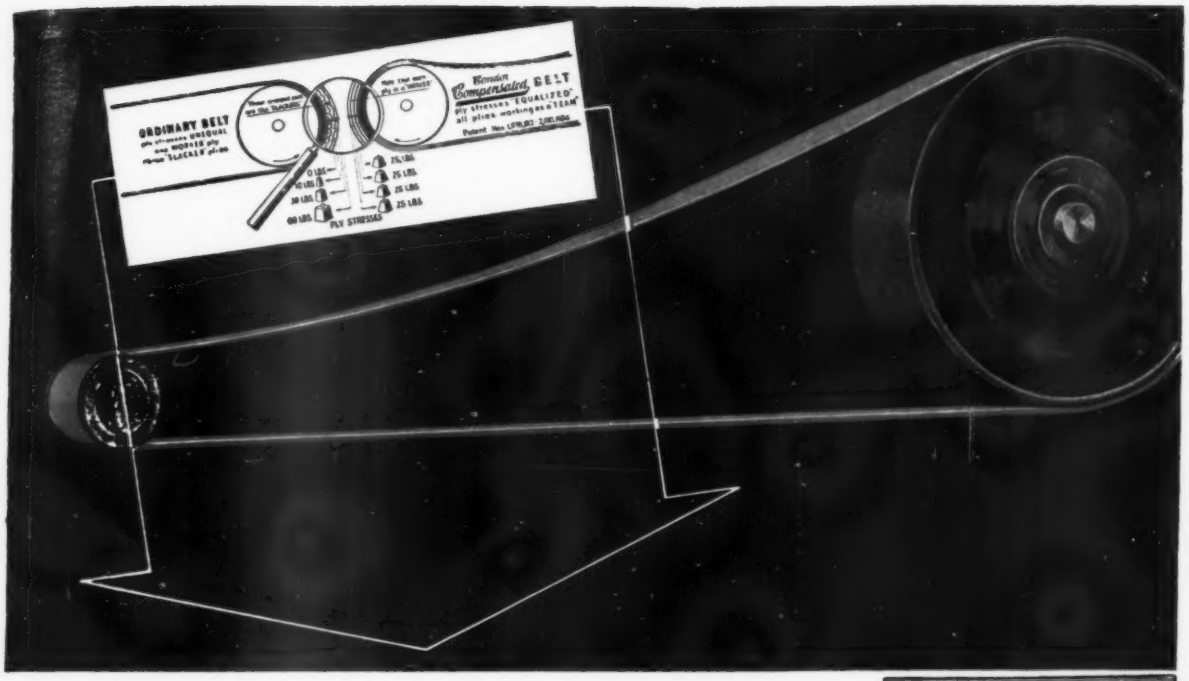

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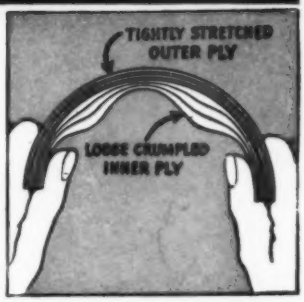

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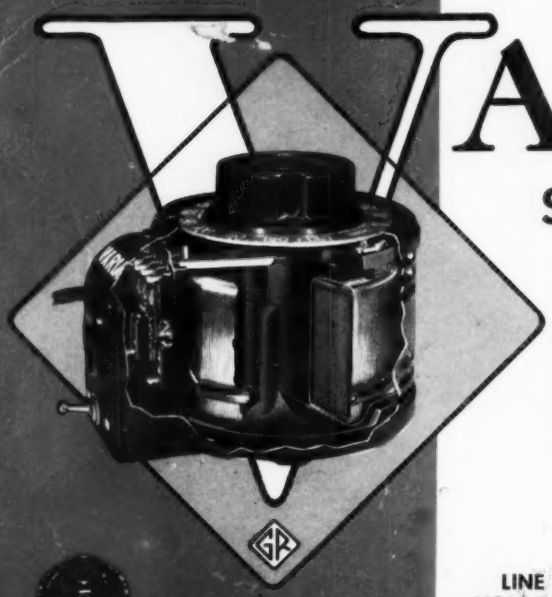

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